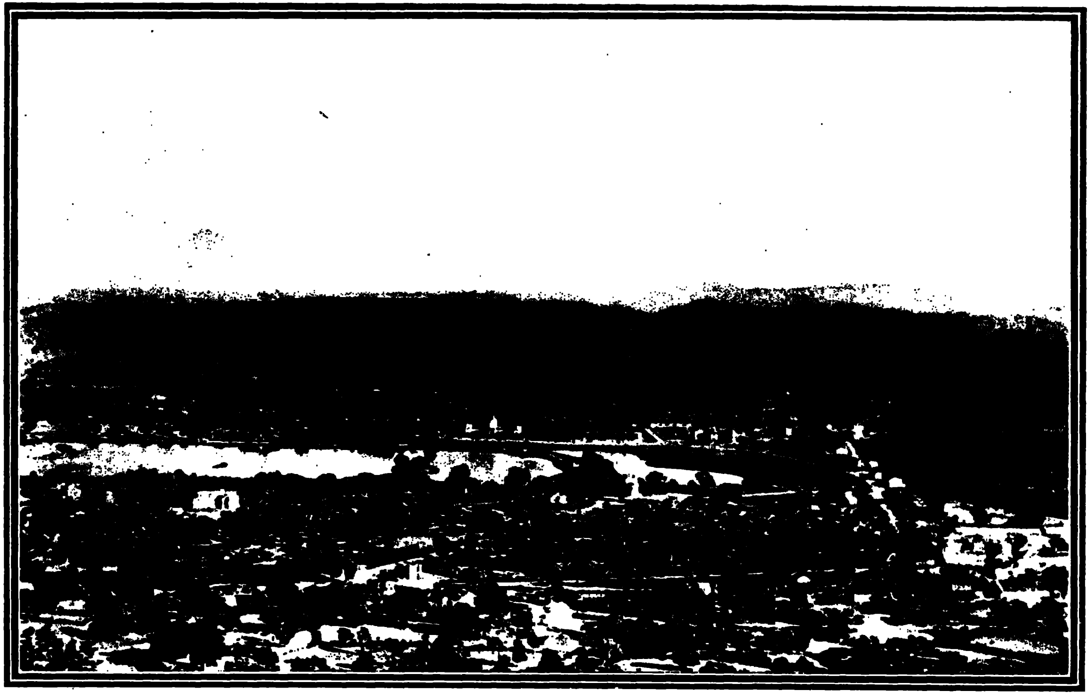

Devgad Baria, with the quartzite ridges in background.
(From the hill Dharamsala, Facing E.-S.-E.)

THE
GEOLOGY OF THE BARIA STATE
(REWAKANTHA AGENCY)

BY

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PREFACE.

In the latter part of 1929, His Highness the Maharawal, Sir Sree Ranjitsinghji, K.C.S.I., Raja of Baria, requested for the loan of the services of an officer of the Mysore Geological Department to conduct a geological survey of the Baria State. In compliance with this requisition the Government of Mysore were pleased to place my services at the disposal of the Baria Government for a period of eight months from 1st October 1930, to carry on that work. Immediately after joining duty at Devgad Baria, the capital of the State, I started field work on the 8th of October, and from that day onwards till the middle of March 1931 was uninterruptedly engaged in field work. Completing the preliminary mapping of the State by this time, I returned to headquarters for a few days to co-ordinate the results of the work done. Again I left for field on the 2nd of April and was camping out for another three weeks attending to some prospecting work and also examining portions of the areas on which I had some doubts. During the field work I camped altogether at 25 places and was able to examine the country in as much detail as the conditions permitted. The work sheets were on a scale of 1 inch to a mile from which a geological map of the State on half that scale, *i.e.*, 1 inch to 2 miles, has been prepared for this publication.

Though this work was undertaken solely at the request of the Baria Durbar, I would be failing in my duty if I were to omit expressing my sense of appreciation for the excellent arrangements got done for my camp movements, especially in a country which by no means can be regarded as ideal for cart traffic in the hilly portions of the interior.

It is a pleasure to me to recall the keen interest which His Highness used to take in the results of my work during its various stages of progress and I have to acknowledge with deep gratitude his ready accessibility, and his uniform kindness and courtesy towards me during the period of my sojourn in his State. My special thanks are due to Rao Bahadur Mr. Motilal Parekh, the Dewan of Baria, for personally looking after the necessary arrangements to render my stay pleasant and comfortable.

I have freely indented on the services of Mr. Malcan, the P.W.D. Engineer who ungrudgingly gave his time for my needs. To him and to various other State officials who rendered me the requisite help in their respective spheres, I am greatly obliged.

I am no less indebted to the officers of the Mysore Geological Department for the diverse ways in which they have aided me. First and foremost I have to express my indebtedness to Mr. P. Sampat Iyengar, Director of Geology, for his numerous suggestions and helpful criticisms on my field notes which I used to send him from time to time. To him and to Mr. A. M. Sen, Officiating Director of Geology, my best thanks are due for having permitted me to draw up this report in the Geological Office, and for having given me all the necessary facilities to get the maps and sections prepared there. To Mr. M. B. Ramachandra Rao, Junior Assistant, I am specially thankful for the untiring zeal with which he collected for me from existing literature information on certain points which I was badly in need of, in the field. He has also drawn for me the geological section. I thank Mr. Sripada Rao, Lecturer in Geology, Central College, Bangalore, for his valuable help in the photo-micrographic work. To Mr. L. Rama Rao, Assistant Professor of Geology in the same College, I am indebted for the identification of the fossil shells.

The map and the sketches for the line blocks have all been done for me by Mr. B. A. Joshi, Head Draftsman of the Mysore Geological Department, to whom I am greatly thankful. Last but not least, I have to thank Messrs. The Bangalore Press for their prompt and neat execution of this printing work entrusted to them.

BANGALORE,
December 1931.

B. RAMA RAO.

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THE GEOLOGY OF THE BARIA STATE, (REWAKANTHA AGENCY).

CHAPTER I.

Introduction.

Extent.

The Baria State with which this report deals forms one of the petty States in the Rewakantha Agency, Bombay Presidency, and is comprised within the wild and mountainous tract that skirts on the east the Province of Gujerat. It has an area of 813 square miles and extends between 22°21′—22°50′ north latitude and 73°4′—74° east longitude.

Boundaries.

The State is bounded on the north by the Rewakantha Estate of Sanjeli, on the east by Jhalod and Dohad sub-divisions of the Panchmahals, on the south by the Rewakantha State of Chhota Udepur, of Kathiawar under the Bhopawar Agency and the Bhil estate of Jumbughoda in the Panchmahals, and on the west by Kalol and Godhra sub-divisions of the Panchmahals. It is triangular in shape. Its greatest length is 39 miles from north to south, whereas its width narrows from about 45 miles in the south to eight miles in the north.

Physical features.

To the west the country is mostly flat being broken up here and there by isolated hills. To the south the hills are higher and more connected until along the frontier they form an almost unbroken line stretching east and west forming the water-shed between the Mahe and the Nurbadda. This line forms the extreme western outskirts of the Vindhyan range. To the east a similar chain of hills, or more strictly a line of tableland of an altitude of 800—1,200 feet stretches north from the Rattanmahal hills forming the water-parting between the Mahe and the Banas. From this range many side spurs run west falling in height and importance as they stretch further from the tableland. North of the Panam

river long lines of hog-backed hills run north-west nearly parallel with the boundary of the State till they reach Sanjeli to the north of which these chains bend eastwards forming a complete arch. None of these rise to more than 1,200 feet above the sea-level.

Rivers.

The principal rivers of the Baria State are the Panam and the Hadap. Among the others the Goma, the Kharod, the Gorukar, the Walwa and the Kubutri might be mentioned. These principally have their sources in the country itself and are mostly tributaries of the Mahe. Some of them become formidable streams during the rainy season, but their channels are wholly or partially dry during at least one-half of the year. The Panam flows north-west from the Rattanmahal hills dividing the State into two unequal parts. The Hadap runs parallel to the Panam about 12 miles to the north of it. Excepting the stream which pursues a north-easterly course passing out of the boundary near Nawanagar, the rest of the rivers have all a main westerly flow.

Climate.

The climate of this State in the interior is said to be peculiarly noxious and unhealthy. This has been principally attributed to the greater part of the country being covered with dense jungles which by preventing a speedy evaporation of water gives rise to unwholesome exhalations. The bad quality of the water strongly impregnated with vegetable matter in its course through the jungles is supposed to be another cause for the reputed unhealthiness. But in spite of my having begun the field work immediately after the monsoon, which is specially noted as the most unhealthy part of the year, myself and my camp followers kept up excellent health during the whole period of our field season.

Temperature range.

The average diurnal range of temperature as recorded during the period (October 1930 to June 1931) was about 20°F. The seasonal range was considerable. The lowest temperature recorded in winter was 40°F. in the third week of December and the highest in summer was 106°F. during the first week of April. During May the maximum temperature varied from 102° to 104°F. Higher temperatures ranging up to 114°F. appear to have been occasionally recorded in some previous years. The annual average rainfall is about 50 inches.

Economic trees and other plants.

Excepting a small portion of the low lying plains in the west, the rest of the hilly portions of the State support dense vegetation of mostly deciduous trees. Teak (Tectona grandis) seems to be prevalent throughout, growing profusely in tracts of the quartzites and the granitic areas, but it seldom attains a girth sufficient to form a valuable timber.

Mohua (Bassia latifolia) thrives well in the low lying tracts of the micaceous and granitic gneisses and I was told that there were no fewer than 75,000 trees in the State. Apart from its value as a useful timber tree, its flowers from which a spirituous liquor is distilled are a favourite article of food of the native tribes of Bhils and Kolis. Eugenia jambolana, Zizyphus jujuba, tamarind and mango grow to a certain extent in the plains, the last generally in cultivated gardens.

Palmyra (Borassus flabellifer) and date-tree (Phœnix sylvestris) are the only two species of palms commonly noticed and these do not seem to be made use of at present.

Bamboo grows to some extent in the Dhanpur jungles and also sparingly in parts of the wooded tracts of Randhikpur. Tall grass grows profusely on some of the plateau regions in the vicinity of Jhabu, Kanakua, Kanajhar and other parts.

Nycthanthes arbor tris-tris, a common garden flowering plant, was found growing wild on the level summits of the quartzite hills near Umria, Nawanagar and their adjacent parts.

The leguminous creeper, Mucuna pruriens (kuvanch), haunts the dense southern jungles and also some of the wooded portions of the eastern parts of the State. The prickly intolerable irritating sensation which the multitudinous velvety glandulour hairs blown by the bursting of the drying brown pods, set up in the body of those who unwittingly pass near the plant, is perhaps an experience common to many.

In some of the plateaus, especially confined to the region of Lameta grits, is commonly found a shrub growing to a height of about six feet, having slender stalks and long lanceolate leaves, (Garab). Unimpeded by any dense undergrowth and forming clusters confined to the regions of grits, the groups of these look almost as if they were diverse blocks of artificial plantations.

Despite the wooded nature of most parts of the State the jungles are not continuous stretches of thick forests favourable for sheltering big games of the types of bisons, elephants and tigers. The tiger seems to be an occasional visitant to the dense jungles of the southern parts. Panther, bear and hyena haunt the rocky caves amidst the boulder strewn hills of Sagtala. Deer of different kinds roam in the grass grown prairie-like lands of the plateau regions. Of other common species of animals, birds and plants, a detailed information can be obtained by a reference to the description of the Baria State in the *Bombay Gazetteer*, Vol. VI.

Big game.

For administrative purposes the State has been divided into seven units called " mahals " as follows :—

Randhikpur and Dudhia in the north; Haveli, Umria and Dhanpur in the middle; and Rajgad and Sagtala in the south. Of these the Haveli mahal is the largest (covering about 200 square miles) in which Devgad Baria, the capital of the State, is situated. This one and also the Rajgad mahal are probably among the best cultivated parts of the State.

Administrative divisions.

Through a pass in the southern chain of hills a metalled road runs from Chhota Udepur, through Sagtala and Baria to Randhikpur in the north. The main road from Godhra to Dohad crosses east and west about the centre of the State. There is a trunk road passing from Piplod through Dudhia to Jhalod. The rest are all fair weather cart tracks connecting most of the parts in the interior, where traffic during the monsoon rains is almost impossible. The capital forms the terminus of a narrow gauge feeder line connected at Piplod with the broad gauge Delhi-Bombay main line.

Means of communication.

Barring the plains under cultivation where the outcrops are few and scanty, the rest of the broken tracts show exposures in abundance. But in spite of these numerous sections, the lines of junctions of different series of rocks as a rule are obscured by talus, debris, forest undergrowth or soil. In many parts of these jungles during the rains and even after, till the end of January, it is difficult to move about freely. An exuberant growth of tall grass hides considerably the outcrops of the underlying formations in the

Accessibility of exposures.

plateau regions. These though hindering the progress of work for a thorough examination of the nature of contacts, do not present any formidable or unsurmountable obstacles to get a general idea of the nature and distribution of the several formations of rocks.

I have no facilities for referring to any exhaustive collections of official records or published notes which might have contained, if any, previous observations on the Geology of the Baria State but from what I can gather this area does not seem to have been examined by any of the pioneer workers in Indian Geology. A brief note on the rocks and minerals of the Rewakantha Agency in general is incorporated in the *Bombay Gazetteer*, Vol. VI, pp. 7-10 and 11-12; and another note pertaining to this, by Major Fulljames in the "Selection Records of Bombay Government," No. 23, pp. 145-57.

Previous observations.

But the areas surrounding, a considerable distance away from this State, have been examined more than once by various officers of the Indian Geological Survey and others. The earliest authentic reference to a portion of the southern fringe of rocks of the Baria State may be presumed to be included among the descriptions of the rocks of the Champaner series by Blanford.[1] In 1905, Dr. Fermor[2] examined a portion of this Champaner series near Sivarajpur, about 10 or 12 miles south of the southern boundary of Baria, in connection with his investigations on the manganese ore deposits of India.

Between 1914-18, a fairly large portion of the Baria State as well as most of its adjoining parts were cursorily examined by Mr. E. J. Beer[3] whose report including a geological map of the area has been published. Unfortunately I was unaware of the existence of this report till the very end of my field season. Despite its being in the shape of traverse notes, yet it furnishes a valuable collection of material to proceed with and as it is the only earlier reference available its value is still more enhanced.

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[1] W. T. Blanford, "On the Geology of the Taptee and Lower Nerbudda Valleys," *Mem. of the Geol. Sur. of India*, Vol. VI, Pt. III, pp. 40–43 and 176–78.

[2] L. L. Fermor, *Mem. of the Geol. Sur. of India*, Vol. XXXVII, Pt. II, Chap. XIV, p. 282.

[3] E. J. Beer, "Notes on Rocks from Pavgarh to Dohad," *Transactions of the Mining and Geological Institute of India*, Vol. XIII, pp. 74–126.

CHAPTER II.

Rock Formations.

According to my identification the following formations as arranged in their descending order are found represented in the Baria State:—

No.	List of formations	Nearest lithological equivalents	Age
5	Soil, blown sand, clay, kankar, calcareous tufa, river alluvium, river gravels and fluviatile conglomerates.	....	Recent.
4	Vescicular, amygdular, compact and porphyritic traps, tuffaceous beds, etc., of the eastern mahals of the State.	Malwa or Deccan Traps.	Cretaceous.
3	(*b*) Infra trappean beds of limestones, conglomerates and sandstones of Jhabu and adjacent parts.	Lameta rocks.	Do.
	(*a*) The sandstone patch on the hill △ 1745.	Nimar sandstone ?	Do.
2	(*d*) The Rajgad shales intercalated with thin bands of quartzites and horn stones, etc.	Phyllite series of Idar and Ajabgarhs(?) of N.E. Rajputana.	Purana. (?)
	(*c*) Quartzites and micaceous schists of the central and northern mahals of the State.	Delhi quartzites of Idar and Alwar quartzites of N.E. Rajputana.	
	(*b*) Felspathic quartzites, conglomerates, mica schists and limestones of the Poyelli region.	Champaner series of Blanford, Raialo series of Dr. Heron, and parts of upper Dharwars of Mysore. ?	
	(*a*) Sillimanite quartzites, grits and micaceous gneisses of the Dhanpur region ?	?	?
1	Hornblende schists, amphibolites, calc-pyroxene granulites, granular limestones, etc., of S.E. Dhanpur and part of Sagtala mahal.	Aravallis, in parts of Idar and Rajputana and lower Dharwars of Mysore.	Archæan.

Igneous Intrusives.

	List of formations	Nearest lithological equivalents	Age
	Pink and grey porphyritic granites and their variations, aplites, pegmatites, etc., of the western portion of the Haveli mahal.	Idar granite; Closepet granitic series of Mysore.	Post-Champaners.
	Pink and grey granitic rocks of Sagtala mahal and Biotite granitic gneisses.	Peninsular gneissic complex of Mysore.	
	Pale grey porphyritic granite, interaction diorite, sericitic quartz-schist, etc., of Chelavad area.	Granitic phases and their modifications of the Champion gneisses of Mysore.	

The oldest recognizable rocks of the State are a group of crystalline schists, consisting chiefly of dark hornblende schists, amphibolites, pyroxene hornblende granulites, and thin runs of pyroxenites and limestones forming the constituents of the archæan complex. These are seen as mere shreds or stringers interbanded with the biotite gneiss covering in all but some 30 square miles of the S.E. corner of the State. Next in succession are a series of quartzites, shales, mica schists, conglomerates and limestones which are largely developed in the State. These form part of the Champaner series of Blanford.[4] These two series of rocks have been invaded by granites and granitic gneisses of probably more than one epoch of igneous intrusion.

Pre-cambrian.

Subsequent to the formation of these crystalline schists with their igneous intrusives, there is a big hiatus in the chronological sequence of the Baria formations till we reach the barely preserved patchy areas of the fluviatile and esturine deposits of the infratrappean beds of the Jhabu plateau. The rocks of this series are also unfossiliferous in this area, but on their lithological characteristics and stratigraphic position, I have correlated them with the Lametas.

Lametas.

Overlying them in parts and sometimes resting directly on the crystalline schists are a series of basic lava flows which may be loosely styled as basaltic traps, forming the outlying patches of the extensive Malwa or Deccan Traps. Subsequent to the outpouring of these traps, there is again a break in the formations of the whole of the tertiary deposits. In some parts of the State are seen loosely bedded or partially consolidated recent materials which are of special import only from their academic point of view. They are confined to some of the river banks in the north and to a few low lying mounds in the plains of the western parts of the State.

Traps.

Recent.

To the south of the Panam the rocks of the archæan complex and those of the Champaner series show a general strike of east and west, the archæan schists striking 5 to 10° W. of N. while the Champaner members to the west of Poyelli swing south and continue in a southerly

General strike.

[4] W. T. Blanford, *Mem. Geol. Survey of India*, Vol. VI.

course. The quartzites and micaceous schists to the north of the Panam show a general strike of north to north-west, but their outcrops in the northern mahals veer considerably to the east from these directions.

The Lametas, the trap rocks and the recent accumulations are all nearly horizontal, the former two capping the plateau regions of the eastern parts of the State lying with a pronounced unconformity on the older rocks.

Comparison with other areas.

The rocks of the archæan crystalline schists and those of the Champaner series have their lithological equivalents among the Aravallis and the Delhi Quartzites of the Idar State and of Rajputana and also among the lower and upper divisions of the Dharwar system as classified by the Mysore Geological Survey. The Geology of the Idar State and that of Rajputana have formed the subject-matters of two comprehensive memoirs from the pens of Mr. Middlemiss[5] and Dr. Heron[6] respectively. The nature, origin and distribution of the Dharwar schists have also been treated in very great detail by the officers of the Mysore Geological Survey.[7]

But there has been a divergence of opinion between these two sets of Geologists regarding the origin and relationship of some of the types like crystalline limestones, quartzites and conglomerates as found developed in their respective localities.

Mr. Middlemiss and Dr. Heron both suggest that the types of these rocks as developed in Idar and Rajputana are essentially sedimentary while the Geologists of Mysore hold the views that the types as found in the Dharwars are primarily igneous in origin. Since types similar to those under controversy have developed to a certain extent among the ancient rocks of Baria, I propose to describe their occurrences in some detail indicating

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[5] C. S. Middlemiss, "The Geology of the Idar State," *Mem. of the Geol. Surv. of India*, Vol. XLIV, Pt. I.

[6] A. M. Heron, "The Geology of North-Eastern Rajputana," *Mem. of the Geol. Surv. of India*, Vol. XLV, Pt. I.

[7] W. F. Smeeth, *Outlines of the Geol. History of Mysore. Bulletin No. 6*, Department of Mines and Geology. See also *Bulletin No. 9* and various records of the Mysore Geological Department.

such of the evidences as might throw some light on this doubtful question.

Results of investigations.

Briefly my investigations tend to suggest that the types of the archæan crystalline schists are all mainly igneous in origin or at any rate do not show sufficient convincing evidences for postulating a primary clastic origin to them. Among the Champaners there are bands which are distinctly sedimentary like the phyllites and slatey schists, ripple marked and current bedded quartzitic sandstones, and bedded crystalline limestones mixed up with distinct igneous intrusives like granite porphyry, porphyry and mica traps. The conglomerates noticed like the majority of those among the South Indian Dharwars are either autoclastic or modifications of types of intrusive breccia. There are some obscure schists which can be distinctly traced to be the altered phases of the igneous intrusives. Besides these types which show some definite evidences, many of the quartzite outcrops have undergone such alterations with the obliteration of all their original characteristics that it becomes impossible to solve at a glance their precise mode of origin. But fortunately even these have got still preserved though very rarely, some sedimentary structures and by a careful scrutiny of field characteristics, correlation of evidences as gathered at different points and on other factors it is possible to suggest that such also had primarily a sedimentary origin, possessing the typical characteristics of aqueous rocks now considerably obscured and altered by dynamical and thermal metamorphism.

The granites have been classified as of different epochs of intrusions of probably two or even three distinct periods. Individually their behaviour in the field and their appearance are strikingly similar to the corresponding granitic divisions of Mysore. The infra-trappean beds of the Baria State are suggested to be of Lameta age. Since among the Lametas the origin of some of the limestones has been attributed by Dr. Fermor and others to the metasomatic replacement of the underlying rocks, the limestone outcrops have been carefully examined. Some of the impure calcareous rocks found in association with the infra-trappean beds are found to be of chemical origin as suggested by Fermor, being metasomatic replacements of the underlying mica schists, but still there is the main mass of the limestone which

could not have originated in this way. By a careful examination in the field it is possible to separate the two. The trap rocks and those of recent age do not call for any special comment, and such of the points as are of special interest are fully dealt with in their respective places.

CHAPTER III.

Archæan Complex.

Types.

As developed in the Baria State, the members which constitute this system are found to be the dark hornblendic schists, felsparless dark hornblendic rocks or dark amphibolites, pyroxene hornblende schists and granulites and their modifications, tremolite-actinolite schists, crystalline limestone, either pure or with serpentine, etc., and bands of grey pyroxenic rocks all occurring as lenticular exposures of various dimensions in the biotite granitic gneiss of the region.

Mode of occurrence.

Dark hornblende schists :—The outcrops of the dark hornblende schist and the amphibolites are seen as thin lenticular ribbons, streaks and stringers inter-banded with the biotite gneisses and are found so intermingled as to render it almost impossible to map them as separate individual units even on the inch scale. The outcrops of these vary from a fraction of an inch to 20 to 25 feet in width, even the largest of such being seldom traceable along their strike for more than 200–300 yards.

Relationship with granitic gneiss.

Aplitic veins and thin stringers of quartz from the granitic gneiss traverse these schists and the edges of the granitic gneiss itself transgress their margins as is noticeable at many points in the ghat section between Kakadkhilla and Dobin phaliya. In the stream bed west of Padalia (Plate 1, Fig. 1) and also in the exposure in the nulla bed ½ a mile south of Gara, pegmatites from the granitic gneisses cut across these schists. The granitic gneisses at their contacts have mingled with them portions of the schists, giving rise locally by hybridization to types of the dioritic gneisses (B/212), hornblende-biotite-granitic gneisses (B/215), actinolitic alaskites (B/218, B/142), etc., as could be seen among the exposures of the ghat section referred to above.

Modifications.

In the Kakalpur village and at other points, the schists have developed near the granitic contacts pale green pyroxene and epidote and rarely garnets. All these evidences clearly point out that irrespective of their mode of

origin the hornblendic schists and their associates have been intruded and piecemealed by the granitic gneisses of the region.

Such intimate association of hornblendic schists and biotite gneisses is a matter of common observation in most of the archæan terranes. The descriptions of specimens from diverse localities do so closely coincide that it would be perhaps impossible to differentiate between the members of one locality from those of another if they were to be grouped together, but yet the explanations offered regarding their mode of origin do vary so very widely that it becomes necessary to detail the characteristics as observed individually in each area.

Macro-character.

The hornblendic rocks of this area occur as highly crystalline well foliated brittle schists or as tough granular semi-bouldery outcrops, dark or speckled, showing black glistening blades and prisms of amphibole and granular patches of salic minerals. Very often thin veins of aplite, or quartz, or streaks of pale greenish epidote are found meandering in them. A few of the outcrops (modified phases) are found banded with pale green streaks of pyroxenes and epidote and darker streaks of amphibole.

Micro-characters.

The micro-sections of these specimens are seen to consist essentially of hornblende, felspar and ilmenite; sphene, apatite, epidote, zircon, quartz and leucoxene are also found as accessory or alteration products. In texture they vary from coarse hypidiomorphic granular to granular and schistose varieties giving rise to variable types.

The amphibole of all these types is a dark glistening variety, either bladey or prismatic. In section it is of a deep greenish blue colour, highly pleochroic showing the following colour scheme:—

$\mathfrak{c}$ — Greenish blue.
$\mathfrak{b}$ — Yellowish green.
$\mathfrak{a}$ — Greenish yellow.

The maximum extinction angle observed $c' \wedge \mathbf{c}$ is up to 20°. It is almost fresh in many of the sections, very rarely giving rise to epidote, but not to chlorite. The species seems to correspond to the common green hornblende or Carinthine.

Of the salic minerals felspar is the most common. Generally it is noticeable as small multiple twinned prismatic sections showing from its extinction angle of about 8° from 001, the characteristics of andesine. Oligoclase also is found to a certain extent. In some sections (B/209) the felspar crystals show mere strain shadows, in others (B/212) they are broken up into granular groups accompanied by granular quartz. The felspar is either fresh, or altered into sericite and quartz (B/21) or into opaque kaolinic patches (B/215). Ophitic relations with the hornblendes are not clearly discernible in any of the sections.

Ilmenite when present is found either granular or as skeletal crystals. In B/209 it is seen altering into cloudy bluish grey leucoxene.

Sphene is found either as greyish grains, or as dusty aggregates mostly secondary or as fairly coarse slightly brownish patches (B/215). Zircon, apatite and pyrites are all accessory and are found in specimens taken near the granitic contacts.

The amphibolite and semi-amphibolite types differ from the above only in containing very small proportion of felspar or quartz.

Tremolite schists.

Ultrabasic Rocks :—Forming almost the edge of the hornblende schists about 5 to 7 furlongs to the south and south-west of Bhanpur village are found a few thin bands of a tremolite-actinolite schist. They are 6 to 8 feet wide, rudely schisted, and are traceable for about 3 to 4 furlongs beyond which they get lost in the heavily wooded precipitous glens. The type consists mostly of brownish-grey fibrous felted tremolite and some pale greenish grey actinolite with their alteration products talc and chlorite. The rocks are very soft and get easily bruised under the hammer (B/213). They are too soft for slicing.

General characters.

Hornblende—Pyroxene granulites :—Pyroxene is not a normal constituent of many of these hornblendic runs, but where they are penetrated by thin aplitic veins or when they occur as small isolated patches in the granitic gneisses, then the mineral is found developed as pale greenish plates. The rock in such cases gets generally banded with pale green and darker streaks or layers

and also becomes very tough quite distinct to the normal dark coloured hornblendic schists. In sections these types show very pale green to almost colourless pyroxene (diopside) as in B/27, sometimes edged with blue green hornblende (B/28). Honey brown wedge shaped grains of sphene and epidote are generally noticeable. Felspars and quartz are often absent. A few outcrops of this type are found as thin runs amidst the granitic gneisses to the west of Kakalpur.

Mode of occurrence.

Pyroxenites.—(Diopsidites). Apart from such occurrences of pale green pyroxene in the hornblendic schists, there are found outcrops of a tough pale greenish grey to ash grey coarse grained pyroxenic rock as intercalated bands in the granitic gneisses, having the same relationship with them as the rest of the crystalline schists. The outcrop seen on the northern flank of the ridge ½ a mile east of △1475 looks almost like a coarse grained felspathic pegmatite. The one seen on the western flanks of the ridges south of Piplidora about 1½ miles N.-E. of △1158 is again a thin band of about 4 to 5 feet wide. This is in association with a thin band of dark amphibolite. In both these areas owing to the dense jungle it was impossible to trace the outcrops. The sections of the specimens from these two outcrops (B/216 and B/219) show coarse platey or granular colourless pyroxene. This pyroxene is well cleaved, shows an extinction angle up to 43° and is optically positive. It shows the normal refringence and bi-refringence of diopside. The mineral partially analysed (by Mr. E. R. Tirumalachar, Assistant Chemist, Mysore Geological Department) gave the following results :—

Optical properties and chemical composition of the pyroxene.

SiO_2	..	51.40	%
Fe_2O_3	..	5.71	„
Al_2O_3	...	5.97	„
CaO	..	23.00	„
MgO	..	13.76	„
		99.84	„

The chemical composition as well as the optical properties point out the species of pyroxene to be a variety of diopside. In

B/219, there are a few grains of pale brownish sphene, in B/216 there are in addition a few scales of honey brown mica (phlogopite).

Associated amphibolite.

The amphibolite in association with the Piplidora outcrop (B/216) is a dark coarse type showing in section coarse plates of amphibole with a striking pleochroism having the same scheme of colours as that of the hornblendic schists of this area, *viz.* :—

c	—	Blue.
b	—	Green.
a	—	Yellow.

This amphibolite (B/217) does not show a single crystal of pyroxene in the slide.

General character.

Limestones :—A number of limestone bands are found as thin lenticular runs intercalated with the biotite gneiss like the rest of the types noted above. These are chiefly found in the northern parts of the Sagtala mahal confined to a narrow zone bordering the normal granites. They vary from pure white fine grained crystalline marble (B/143), to impure types which show garnet and colourless granular pyroxenes and olivine, near their contact with the granitic members. Oily green serpentine, weathering yellow, as in B/145 is found along with other minerals in some of the exposures.

Gara exposure.

In the big nulla joining the Panam river about ½ a mile due south of Gara, there is an interesting complex exposure. Bordering a run of coarse pegmatitic gneiss is a band of highly crystalline serpentine marble. Apparently overlying this is a band of micaceous hornblende schist and feathery actinolitic amphibolite. Patches of dark amphibolite are also seen in the serpentine marble. In the hornblendic micaceous schists are veins of granite, 2—2½ feet wide and a number of aplitic stringers 3 to 9 inches wide sheared here and there. The whole series has been gently folded, strikes W. N. W. and dips north at 50°—60° and is only traceable for 200 feet beyond which it is lost in soil. The following sketch (Text Fig. 1) gives an idea of the distribution of these various types :—

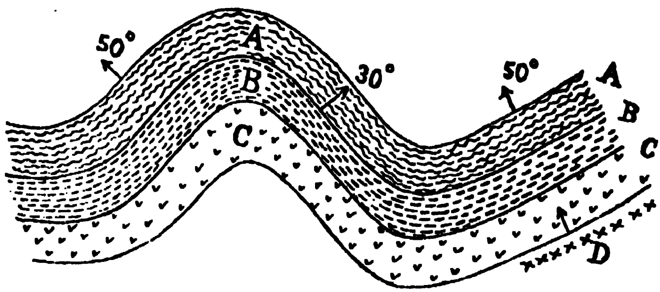

Fig. 1.

A. Dark grey amphibolite. C. Granitic gneiss.
B. Serpentine marble. D. Pegmatite.

Description and field relations.

The limestone varies from greyish white to dark grey studded with granular patches of oily green serpentine altering superficially into flakey yellowish green opaque patches. In section the lighter grey band (B/171) shows coarse plates of calcite and dusty granular carbonates with patches of colourless or brown stained serpentine. There are also a few crystals of a scaly or flakey pale green almost non-pleochroic mineral which has a micaceous habit, ill-developed cleavage, moderate refringence and bi-refringence. The refractive index approaches that of muscovite, but the double refraction is slightly less. The extinction is almost parallel. The flakes are bent and frayed. These are not very conspicuous in the hand specimens and are seen as small irregular greenish black plates with brilliant lustre. It is probable that the mineral belongs to the group of brittle micas. Opaque cloudy patches with minute relict dots of ilmenite and dark steel grey granular magnetite are found in fairly large quantities. The specimen from another portion just near the border of the amphibolite (B/172) shows an equal proportion of similar calcite and large plates of pale green serpentine dotted with minute grains of iron ore. The serpentine is seen in feathery or fibrous aggregates sometimes mixed up with relict amphiboles confined to areas suggestive of prismatic sections. The iron ore is all ilmenite. The micaceous mineral also is noticeable as bent flakes,

but here all the flakes show a very low double refraction. In this limestone band are small patches of the dark grey amphibolite. This band passes or grades upward into a dark grey, platey or fibrous amphibolite which in outward appearance differs somewhat from the dark amphibolite of the typical hornblende schist series. The micro-section of this type (B/173) shows coarse plates or patches of pale yellowish green amphibole dotted throughout with leucoxenic and sphenic altering ilmenite. The amphibole on account of its pale colour does not show any striking pleochroism.

The colour seems to vary from pale bluish or lavender grey to almost colourless or pale yellow, but still the absorption scheme is the same as that of the rest of the amphiboles of this area, *viz.*, $\mathfrak{c} > \mathfrak{b} > \mathfrak{a}$. It shows an extinction angle of about $16^{\circ} c' \wedge \mathfrak{c}$. A small portion of zoisite is noticeable as an alteration product but calcite is not distinctly seen. The specimen of amphibolite (B/176) taken away from the limestone band shows large plates of pale green to almost colourless amphibole with a considerable amount of iron ore dust and grains of ilmenite.

Nadatod exposure.

To the north of Sagtala are found similar lenticles of granular crystalline marble. About ½ a mile N.-W. of Nadatod there is a small lenticular band of crystalline limestone, exposed in a small nullah, associated with the biotite gneiss and thin pegmatites carrying platey crystals of labradorite. The normal type of limestone is a greyish white crystalline marble (B/143), but just near its contact with the pegmatite it has developed a good deal of pale pink garnets, oily green serpentine and a pearly micaceous mineral pleochroising from pale pink to pale green similar to that found in the Gara exposure. This has in addition grains of olivine(?) and granular iron ore (B/144). But for the presence of colourless olivine and pink garnet this limestone does not differ much from that of the Gara exposure. This band is not traceable for any long distance, but proceeding westwards the granitic gneiss shows lumps and patches of amphibolite in the continuation of the strike of this band.

About a mile E.-N.-E. of Dabhav hospital is another lenticular run of crystalline limestone more or less resembling the Gara exposure, and this also has developed small grains of

garnet. This is exposed for a length of 50 feet with an average width of 5 to 10 feet.

Actinolite—Quartz schist:—One other member of this crystalline complex, which is found conspicuously to the N.-E. of Sagtala is a type of pitted actinolite quartz schist which outcrops in sinuous bands forming the series of low rounded hills. The rock is light grey or white, foliated and schisted, brittle and harsh and shows small scales of actinolite in a granular quartzite. This is found associated in some places with runs of hornblendic schists and biotite gneisses, at others with the latter rock without any distinct band of hornblendic schist.

The type of rocks described till now are all found as isolated disconnected lenses in the biotite granitic gneisses showing a general trend of direction of W.-N.-W. The zone of this complex assemblage can be traced within the State from near Kakadkhilla for a distance of nearly 30 miles W.-N.-W. with a gradual diminution of width whereafter they almost disappear against the totally different series of the highly metamorphosed mica schists and gneisses, the altered representatives of the Rajgad shales and the intrusive granitic gneisses which will be described later on.

Question of correlation.

From isolated disconnected exposures like these it would be impossible to deduce either the mutual relations of the various types or their probable modes of origin. At the best it is only possible to compare their mode of occurrence and association with similar types developed better elsewhere where they have been studied in detail with greater advantage and see which of the diverse explanations offered regarding their mode of origin would be found applicable here. Of these crystalline schists, it is the calc granulites or calc gneisses and some of the limestones associated with them, which have received the greatest attention in India.

These several types which are found exposed in this narrow belt of the archæan schists of Baria have their lithological equivalents among the Aravalli system of the Idar State and of Rajputana, among the archæan complex of the Central Provinces, among the lower division of the Dharwar schists of Mysore and probably among many an other zone of the archæan crystalline schists.

Views of Mr. Middlemiss regarding the origin of calc gneiss, etc.

Among the Aravallis of the Idar State there is a larger development of the "calc gneisses" and the pyroxenic rock than are noticeable in this area, but the amphibolite (or hornblende schists) are found only as thin layers of ¼ to 1 or 2 inches across in the limestone.[8] The "calc-gneisses" of the Idar State like the limestone bands of this area are in close association with the non-calcareous biotite gneisses. In discussing their mode of origin Mr. Middlemiss favours the view of their being a metamorphic sedimentary series.[9] Similarly the pyroxenic beds of Bamanwada, Bhetali and other parts of Idar in association with beds of crystalline limestone and quartzose varieties are also suggested by that author to have been formed by the metamorphism of the impure or dolomitic limestone.[10] The origin of the amphibolite bands which seems to have a striking resemblance to the feather amphibolites of the Halliburton and Bancroft areas described by Adams and Barlow, has not been fully discussed though Mr. Middlemiss seems to incline to the view of those Canadian Geologists in regarding them as altered sediments.[11]

Heron's views.

The crystalline limestones and the micaceous schists among the Aravallis of Rajputana are also thought by Dr. Heron[12] to be the highly metamorphosed sediments. But the amphibolites of that area corresponding to what are here described as dark hornblende schists are stated to be dykes[13] traversing irregularly the granites in all directions. Amphibolites in association with the crystalline limestones and also the grey pyroxenic rocks comparable to those of Idar and of Baria have not been noted by this author as occurring among the Aravallis of Rajputana.

Views of Fermor and Burton.

The limestone outcrops and the calc gneisses (calc granulites) similar in character to those under consideration here, of the Chhindwara district, Central Provinces, have been repeatedly studied by Dr. Fermor and the various modifications of his views from what he originally

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[8] C. S. Middlemiss, *The Geology of the Idar State*, *op. cit.*, p. 43.
[9] *Ibid*, Do. do. p. 43.
[10] *Ibid.*, Do. do. p. 72.
[11] *Ibid.*, Do. do. p. 63.
[12] A. M. Heron, *The Geology of North-Eastern Rajputana*, *op. cit.*, p. 15.
[13] *Ibid.*, Do. do. p. 16.

expressed in 1903 to that which he subsequently holds have been summarized by Mr. Middlemiss.[14] Dr. Fermor agreeing with the late Mr. Burton appears to regard now these calc granulites, as mixed gneisses,[15] the hybridism at least in part being effected by the *lit-par-lit* intrusion of the calcareous rocks by an acid magma.

Mr. West, examining the mode of origin of the calc granulites of Utekata ridge, has suggested the possibility of the banding being due to some kind of seasonal variation during sedimentation.[16]

With the possible exception of Dr. Fermor's original view which suggested the calc granulites and limestones of the archæans of Chhindwara as the chemical alterations of a highly calciferous pyroxene gneiss the present views of the officers of the Indian Geological Survey seem to be inclined to regard them to have been originally impure calciferous sediments. In this connection it is interesting to note that Dr. Fox has described a case near the village of Mankughati in which a band of amphibolite seems to have been marginally converted into a crystalline limestone. (*Vide* General Report, *Geol. Surv. of India*, Vol. XLV, Pt. II, p. 130.)

Views held by Geologists in Mysore.

Among the Dharwar schists of Mysore, the dark hornblendic schists and their felsparless variants or amphibolites, calc-pyroxene-hornblende granulites and the crystalline limestones of the lower division have all been regarded as primarily igneous in origin. The dark hornblendic schists of the Kolar Gold Field and other parts of Mysore have been shown to be the metamorphosed representatives of basalts and dolerites and the tough banded calc-pyroxene-hornblende granulites or the "secondary pyroxene" rocks to be the altered portions of the dark hornblende schists at their contact with acidic veins or granites.[17] The mineral composition of this latter type originally described under the name "Tarurite",[18] is very variable containing amongst others, calcite, epidote, pyroxene,

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[14] C. S. Middlemiss, General Report *Rec. of the Geol. Sur. of India*, Vol. XLV, Pt. II, pp. 100-102.

[15] *Ibid.*, General Report, do. do. Footnote to page 102.

[16] E. H. Pascoe, General Report, *Rec. of the Geol. Surv. of India*, Vol. LIX, Pt. I, p. 115.

[17] W. F. Smeeth, *Bulletin No. 3*, Mys. Geol. Department.

[18] E. W. Wetherell, *Rec. of the Mys. Geol. Dept.*, Vol. IV, Pt. II, p. 88,

biotite and garnets in variable proportions. Some of the limestone runs of this lower division bordering the hornblendic schists in contact with the granitic gneiss are believed to be the extreme modifications of this type,[19] though this view has not been generally accepted.[20]

The grey pyroxenic rocks comparable to those noted in the Baria State are rather rare in the Dharwar system and so far as I am aware somewhat similar occurrences have been noticed but rarely in the charnokite areas of southern parts of Mysore.[21] The only exposure of this type of rock which I had an opportunity to study in Mysore was in the vicinity of Nanjangud where a calcite-scapolite pyroxene rock is found as a narrow meandering band in association with dark garnetiferous hornblende granulite intruded and cut up by a coarse grained pegmatoidal granitic gneiss of the area. The series of rocks in that area are thoroughly crystalline and there are no types in association which could be recognized as definitely sedimentary. There are gradations from a pure garnetiferous dark hornblendic schist through types containing a fair amount of calcite and pale green pyroxene to those in which there is no hornblende at all. Doubtless this is a continuous series of alterations and either the hornblendic granulite will have to be regarded as a re-fused, recrystallized mixed argillaceous and calcareous sediment or the calciferous rocks to be the thermally metamorphosed products of the modified hornblendic schists. A re-fused recrystallized sediment cannot be easily differentiated from the types which have normally solidified from a molten magma. In the absence of very positive evidences, it would serve no useful purpose in adopting that line of speculation. Therefore on the analogy of the formation of secondary pale green pyroxene from the recrystallization of hornblende as seen in the Kolar Gold Field area it was considered that the calciferous pyroxenic rock which is seen as a marginal fringe of the hornblende granulite at its contact with the granitic gneiss was the contact altered modification of the hornblende granulite itself. (Compare specimens $\frac{M1}{843}$, $\frac{M1}{845}$, $\frac{M1}{846}$, $\frac{M1}{847}$ and $\frac{M1}{848}$.)

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19 E. W. Wetherell, *Rec. of the Mys. Geol. Dept.*, Vol. V, Pt. II, pp. 3-7.

20 B. Jayaram, *Rec. of Dept. of Mines and Geology* (Mysore), Vol. XVIII, Pt. II, pp. 59-63.

21 B. Jayaram, *Rec. of the Mys. Geol Dept.*, Vol. XIII, Pt. II, p. 91.

Briefly then the position is this:—excepting the dark hornblendic rocks of Rajputana which Dr. Heron regards as dykes the rest of the series of rocks, *viz.*, calc gneisses, parts of biotite gneisses or mica schists, pyroxene rocks and amphibolites of the Aravallis are all regarded by Mr. Middlemiss and Dr. Heron as altered sediments whereas similar types of rocks among the Dharwar system are held by the geologists of Mysore to be the modifications of igneous rocks.

Discussion regarding the mode of origin of the archæan rocks of Baria.

Now to revert to the archæan crystalline schists of Baria:—

Hornblende schists.

The dark hornblendic schists of this area like those in the Dharwars and also of Rajputana have no vestige of original pyroxene in them. In general appearance, texture and structure, association and mode of occurrence they have a striking resemblance to the members of the Dharwar system. The well preserved multiple twinned lath shaped and prismatic felspars are evidently the results of crystallization from a molten mass. But unlike the Kolar hornblendic schists, these do not occur here in a solid belt, are generally coarser textured and do not show any signs of granulitization. Whether they are actually consanguineous with those or not there is nothing at any rate which forbids us from postulating a similar mode of origin to these schists as that of some of the hornblendic schists of Dharwars. The amphibolites of the Idar State do not resemble the hornblende schists of Baria in their mode of occurrence, and those of Rajputana though probably of similar appearance cannot be correlated with them as they are found to be intrusive into the granites.

Hornblende-pyroxene granulites.

The banded pyroxene hornblende granulites, like those in Mysore, have got their pyroxene developed secondarily as a result of contact action along the borders of acidic veins. It has been clearly shown by Dr. Smeeth[22] that this pale green pyroxene is a secondary mineral developed at the expense of amphibole as a result of contact metamorphism. The evidences noticeable here all point

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[22] W. F. Smeeth, *Bull. No. 3*, Mysore Geol. Dept., p. 7.

to the same conclusion and the arguments adduced to the Kolar Gold Field occurrences might as well be repeated here.

Pyroxene rocks.

The few occurrences of the grey pyroxene rocks noticeable in Mysore tend to support the view that they are the extremely modified phases of a hornblendic rock. In the Baria occurrences the evidences are not so very clear, as these types are not seen contiguous with the hornblendic rocks. In association with Piplidora exposure, no doubt there is an amphibolite band but this is separated from the pyroxenic rock by at least a width of 50 to 60 feet of biotite gneiss. Some of the hornblendic schists of the area have developed pale green pyroxene, as already noted, but a similar pyroxenic rock has also been found as thin lenses and bands amidst the impure phyllites of the Rajgad shales, a sedimentary series, where they are traversed by pegmatites not far from the granitic contacts. In the latter instance no hornblendic schists were noticeable in association. It is therefore doubtful as to how far one will be justified in attributing a purely igneous mode of origin to such rocks in the absence of distinct acceptable proofs. But still due to the fact that pyroxenes akin to those under consideration *have* developed in the region secondarily in the hornblende schists, and due to the possibility of larger masses resulting as contact modified phases of similar rocks as noticed elsewhere (in the vicinity of Nanjangud as already referred), due to the absence of any distinct bands of calcareous rocks in association and due to the association though somewhat remote of crystalline hornblende schists and amphibolites, I am inclined to view the pyroxenic rocks also as extreme phases of modification of the dark amphibolites. The progressive stages of this metamorphism seems to me to have been the primary conversion of the amphibolite into the impure limestones, such as those noted below and their reconversion into the present diopside rock as a result of intrusion of the later sets of pegmatites and granites of the Haveli porphyritic granite series.

Limestones.

The limestones of the archæan complex of the Baria State differ from those of the Aravallis in being dolomitic or magnesian. In the field these are massive and unbanded. Texturally they show coarse plates of calcite showing lamellar twinning and traces of cleavage

very well. They differ also in some respects, in appearance, in having serpentine, brittle micas, and olivine or chondradites as their constituents from the types of the limestones of the Lower Dharwars. Many of the Baria exposures occur as isolated lenses in the biotite gneisses unassociated with the hornblendic schists, but along the strike of such on either direction are found isolated masses of the dark amphibolite in the biotite gneisses. But in the Gara exposures already described, the amphibolite and the limestone are juxtaposed yielding a definite section for a closer study. Here the mode of occurrence and association of the amphibolite and limestone as distinct individual bands in close association with igneous rocks suggest one or other of the following probabilities for their mode of origin :—

(1) Amphibolite and the limestone both being originally sediments now represent the metamorphosed phases of the argillaceous and calcareous series of rocks respectively.

(2) The amphibolite and the limestone being the altered phases of rocks which were probably in the form of differentiated stratified sills, the more basic magnesian layer forming the lower portion of the sill.

(3) The amphibolite might be the metamorphosed phase of the sedimentary limestone.

(4) The limestone might be an altered phase of the amphibolite of originally igneous origin.

The evidences for and against these suggestions might now be briefly dealt with :—

(1) The region to the south of the Gara exposure consists mainly of the granitic gneisses without the intercalation of any distinct series of calcareous sediments. To the north no doubt there is a wide stretch of micaceous gneisses and schists of doubtful origin, but on account of their distinct foliation and the absence in them of all signs of stratification and owing to their being traversed by numerous pegmatites and aplites which characterise the zone of distinctly recognizable granitic gneisses, the micaceous schists have to be regarded as highly weathered phases of the biotite granitic gneisses of the region. Neither the limestone nor the amphibolite show any traces of lamination amongst themselves and therefore in the absence of positive proofs, the

pre-existence of a definite series of both argillaceous and calcareous sediments cannot be surmised. Besides, the occurrence of patches of the amphibolite in the limestone band clearly suggests that both could not have been deposited in the area as original sediments.

(2) To regard the amphibolite and the limestone as having resulted by separate processes of alterations of differentiated phases of an igneous rock, there is not much evidence in the field. In some places there is only the limestone unconnected with the amphibolite and in others only the amphibolitic patches without the limestone. Though gradational stages have not been found between the two, still since in the strike of the limestone band are often found lumps of the dark grey amphibolite it is suggestive that one might be the derivative of the other.

(3) Is the amphibolite the metamorphosed phase of a sedimentary limestone? As already stated, there is no definite series of limestone or other calcareous rock in the area. Besides, the position of the limestone band between the amphibolite and the granitic members would show that the amphibolite could not have been derived from the alteration of the limestone, since under such condition the amphibolite would have been found close to the edges of the intrusive rock and not far away from them. The amphibolite is greatly in excess while the limestone occurs only as its thin marginal fringe.

(4) Can the limestone be the altered phase of the amphibolite and could the amphibolite be originally igneous? The occurrence of the limestone lenses along the strike of the bands of the dark amphibolites, the presence of small patches of the amphibolite in the limestone suggesting unaltered remnants, the detection of areas indicating the original existence of amphiboles in the microslide (B/172) of the limestone, and the position of the limestone band in between the amphibolite and the pegmatitic gneiss all point out the possibility of the limestone as having been formed due to the alteration of the amphibolite.

The amphibolite no doubt presents a somewhat different appearance in the field to the felsparless dark amphibolites of the hornblendic schists. In the microslides, the hornblende of this amphibolite is of a paler colour and not highly pleochroic, but

still its scheme of absorption is quite similar to the rest of the hornblendes of this area. The amphibolite contains plenty of grains of leucoxene or sphenic altered ilmenite, a mineral of very common occurrence in the hornblendic schists. These are suggestive, though not conclusive, of the amphibolite in association with the limestone being in no wise different to the felsparless variants of the dark hornblendic schists, and if so, like them of original igneous origin. Possibly the slight difference in colour might be due to the alterations the rock has undergone.

In the vicinity of limestone bands the amphibolite shows thin streaks and veins of calcite, suggesting that the calcareous material got from the breaking down of the amphibole has been deposited as the carbonate under favourable conditions. A continued process of such a change would convert most of the amphibolite into a crystalline limestone. To what extent the intrusion of pegmatite has accentuated or hastened this process is not very evident, but it is clear that its contact effects have brought about some further modifications in the mineral changes.

The calcification, serpentinization and the conversion of ilmenite into sphene might be contemporaneous with or following the intrusion of the Sagtala granite or its pegmatite phase. The production of garnet, olivine, and chondradite (?) as near Nadatod and also the formation of pyroxenes of the diopsidite bands may be due to the effect of intrusion of the later set of pegmatites of the Haveli porphyritic granite series.

Summarizing these descriptions it is clearly seen that in the zone of the archæan complex of Baria, there is no type which can be unhesitatingly pointed out to have had an aqueous origin. Like their compeers the components of the lower Dharwars, they tend to suggest that they had a primary igneous origin and by the secondary processes of alternations they are now so constituted mineralogically as to resemble the types usually regarded as contact altered phases of sediments. If this view is tenable, then all the diverse types constituting the archæan schists of Baria can be regarded as consisting only of an older series of epidiorites or hornblende schists and amphibolites and a later series of intrusive biotite granitic gneisses.

Resemblance of the archaean region of Baria to the Peninsular gneissic complex of Mysore.

In Mysore apart from larger patches of hornblendic schists and their associates which form distinct belts of schists are quite a number of thin bands and stringers of rocks of similar character as intercalated bands or cut out strips in the biotite granitic gneisses occurring scarcely in mappable dimensions to separate them as distinct units. The archæan complex of the Baria State is exactly similar in the mode of occurrence of its constituent types and thus has a greater resemblance to the Peninsular gneissic complex of Mysore with its intercalated thin bands of dark hornblendic schists and their modifications of the lower Dharwars than to the typical Aravalli system of Rajputana.

CHAPTER IV.

The Champaner Series.

The series of quartzites, shales, conglomerates and limestones forming the group of hills to the east of the prominent landmark, the Pavgarh hill, were described by Dr. Blanford in 1869 under the local name of the Champaner series after Champaner, the ancient capital of Gujerat, as the series was believed to differ in some respects from the Bijawar and other transition rocks recognized till then. A reference to his map in the memoir already cited (Vol. VI, *G. S. I.*) shows that Dr. Blanford's examination of this series of rocks was confined to the area south of the borders of the Baria State and as such it is doubtful as to where he would have placed the northern limit of his "Champaner series" and whether he would have attempted sub-dividing the series if he had examined the area further north. In the map attached to his report Mr. Beer colours the whole of the crystalline schists of Baria as of the Champaner series correlating them with the Dharwar system.

Area originally described by Blanford.

Since the series of rocks exposed in different parts of the Baria State differ to a certain extent in their lithological characteristics, I have thought it desirable to describe the diverse groups adopting local names, without intending to connote without further discussion, any definite order or sequence of succession. This aspect of the question of classification and correlation will be reserved for the next chapter. The rock groups will then be described under the name of :—

Division into groups.

(A) The Poyelli group, (B) The Dharia limestone, (C) The Rajgad shales, (D) The Baria quartzites, and (E) The Dhanpur schists.

A. The Poyelli Group.

The rocks of the Poyelli group form the northern fringe of the actual Champaner series of Blanford and pass east and west through the southern borders of the State to the south of Nathpura in the Rajgad mahal. As exposed within this region they consist of the

Extent.

micaceous schist and phyllites, limestone, jaspery hæmatite, conglomerates and quartzites. This series has been acutely folded but my description applies only to that portion of the limb of the fold which is within the Baria State.

Rock Types.

MICACEOUS PHYLLITE.

The lowest member in the area examined is a fine grained sericitic micaceous schist which varies in texture from a typically crystalline fine grained schist to highly weathered structureless grey shaly and phyllitic types. This is not conspicuously developed within the area under consideration.

LIMESTONE.

General characters. Forming the southern boundary of the State in this part, is a well developed band of magnesian limestone, compact, massive and brittle. It is generally dark grey in colour and changes along its strike into a compact greyish white granular type. The limestone is traceable for 1½ to 2 miles within the State, but extends beyond on both the sides. Its width is about 400—500 feet. For the most part it is neither bedded nor laminated, but is intersected by a number of veinlike tough ridges consisting essentially of secondary silicate minerals, the most conspicuous amongst which being a pale clove brown amphibole, tremolite, actinolite, and a silvery white pearly micaceous mineral which seems to be a variety of clinochlore. Thin quartz veins having radiating bunches of actinolite are also noticeable and one of such showed quartz, calcite, magnetite and actinolite.

Micro-characters. The microslides of both the dark grey as well as the greyish white types show a fairly crystalline granular ground of carbonates without any cleavages or twinning, and acicular and prismatic sections of a well cleaved colourless amphibole. In the dark grey variety (B/89) in and around the granular carbonates is a considerable amount of black dusty particles which cannot be resolved even under high powered objectives. Some of the acicular amphiboles are also crowded with this dust. In the greyish white types (B/91, B/100), the carbonates are slightly coarser and granular

and there is also in the latter specimen a larger proportion of the amphiboles and the micaceous mineral. In specimens the amphibole is found as a clove brown variety, bladed or acicular. In section it is seen to be colourless, either prismatic, bladed with one of the ends tapering, or wedge shaped, clear or crowded with black dust, well cleaved having also cross fractures, showing an extinction angle of about 10°—12° from the dominant cleavage cracks. Its refractive index and double refraction are equivalent to those of tremolite or anthophyllite. It is optically negative. The mineral corresponds to gedrite or anthophyllite in its general character, but shows an inclined extinction. The wedge shaped sections form a central core of this amphibole around which and parallel to the edges there is a growth of secondary calcite. The silvery white micaceous mineral is seen in section as colourless or greyish plates showing very low double refraction colours, almost uniaxial and negative in character. It probably belongs to the clinochlore group.

Along the joint planes in the limestones are often found a thin coating of a matted, fibrous, and radiating aggregates of pale green actinolite. Apart from such in the body of the limestone, there are sometimes found along its edges masses of 1 to 2 feet of coarse platey diallage lumps and actinolitic bundles. Here and there amidst this limestone are found very rarely felspathic granulite blocks or boulders which look almost like a crushed granite. Immediately beyond the western boundary of the State, the limestone has thin veins of epidote and blocks of a very handsome pink and green actinolitic quartzose rock (B/410). On its southern side the limestone has patches of jasper and jaspery hæmatite apparently forming a thin overlying cap mixed up with dark grey quartz and coarser masses of actinolite. I presume the limestone is underlain by a patch of intrusive granite, the modified offshoots of which are found in the limestone as felspathic granulites as noted above, the region being not yet sufficiently dissected to show the granite below. The large development of the secondary minerals may perhaps be partly due to such an intrusion.

To the north overlying the limestone is a thin band of dark bluish grey slatey argillite obscurely exposed here and there. This is well jointed and shows a dip of 80° to the north.

PORPHYRY.

This is immediately succeeded by a tough bouldery dark grey porphyry which is variable in character. It is a medium coarse dark grey crystalline rock showing small plates and roundish spots of pale greenish grey felspar and dark glistening bunchy aggregates of biotite. To the west it tails to a point and is lost in soil while to the east along its strike it gets schisted and passes into a dirty bluish grey micaceous phyllitic schist showing blebs of dark grey or bluish opalescent quartz. On this side also it gets very thin and disappears as thin bands and veins in the compact phyllitic schist.

The schisted type with its blebs of opalescent quartz reminds me of the "stretched sericitic grits",[23] an altered phase of the quartz porphyry of the champion gneisses of Mysore. In its central part due to its dark grey colour owing to an abnormal development of mica the rock looks almost like a basic dyke. The microsections of this show however variable quantities of biotite of a pale greenish-brown type, and coarse plates of felspar charged with granular epidote, small patches of green chlorite and a small portion of scaly sericite as alteration products. Larger crystals of yellowish green epidote and grains of magnetite are also seen (B/415, B/416 and B/417). Felspars are seen to be both orthoclase and plagioclase, the latter predominating. Small grains of quartz distinct to the opalescent blebs are noticeable and these are seen to be secondary. The schisted type (B/418) from the eastern end, shows under the microscope the felspars crushed into augens, the orthoclase completely broken down while the plagioclase is comparatively fresh showing still its multiple twins. Quartz is found either as rounded blebs or as slightly compressed drawn out grains. This mylonitization of the type is due to the rock forcing itself along narrow channels of passage in the pre-existing shales and schists. These different phases or variations of the type may be styled as schisted quartz porphyry, orthoclase porphyry, and micaceous porphyry, but the greater portion of the exposure is distinctly melanocratic and approaches in character, the minette and kersantite types of the lamprophyre group.

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[23] B. Jayaram, *Rec. of the Mysore Geological Dept.*, Vol. XIV., Pt. II, p, 91 and also Map, Plate 1, *Rec. of the Mys. Geol. Dept.*, Vol. XVI.

The intrusion of this dyke has not brought about any striking changes in the invaded rocks. The bluish argillitic schists to the south have developed a secondary slatey cleavage and the quartzitic sandstone or felspathic quartzite to the north has acquired a few crystals of tourmaline.

Conglomerates and Grits.

Description of "Conglomerate" rock.

In the Poyelli village, the northern edge of this rock is hidden under soil, but after an interval of a hundred feet or so further, bands of sericitised conglomeratic grits and quartzites are noticeable. The conglomeratic bed is variable in character. Near the Poyelli waterfall it is about 8 to 10 feet wide, almost vertical dipping at 85° to the south. Here it forms a coarse grained heterogeneous quartzitic mass showing in its matrix blebs of opalescent blue quartz and also small patches of dark grey gritty portions. Thin veins of quartz are noticeable. Pebbles are scarce and where seen are found as light to dark grey quartzite varying in size from that of a pea to 2 inches across. Westwards this band passes into a conglomeratic breccia (Plate 1, Fig. 2) having angular patches of similar quartzite in an undifferentiated gritty siliceous matrix. Further west near the footpath leading from Poyelli to Nathpura, the band again assumes the character of a sericitic gritty quartzite containing occasional perfectly rounded smooth dark grey quartzite pebbles. About ½ a mile to the S.-W. of this point just beyond the western borders of the State another exposure of the conglomerate of about the same thickness is noticeable dipping here apparently beneath the limestone at about 50°. Here the outcrop is very coarsely conglomeratic (Plate 2, Fig. 1), the pebbles consisting of dark grey quartzite, light grey quartzite, pinkish quartzite, tourmaline quartz schist, and milk white reef quartz. These pebbles vary in size from about an inch to 18 inches in diameter. In addition to these there was only one squarish patch of 2″ × 2″ of dark grey slatey schist. The matrix is fine grained sericitic and siliceous and contains bluish opalescent quartz. Small quartz veins which are in themselves discontinuous pass indiscriminately through both the matrix and pebbles. Joints also behave similarly. There has been a rude sorting and at certain points the coarsest boulders are closely packed as if dumped there. This description shows

that portions of the outcrops create an impression of the band being truly sedimentary, but a closer investigation of the evidences points otherwise.

About a couple of miles westwards in the continuation of the strike of this band is again noticeable a rudely schisted coarser textured sericitic grit with squashed lenses and lumps of dark grey quartz of very small size, ¼″ or so. This has no conglomeratic structure.

The conglomeratic bed does not occupy a persistent definite horizon. It is in between the porphyry band and the quartzite, or between the quartzite and the limestone or between the latter and the micaceous phyllitic schists.

"Conglomerate" not sedimentary.

The general dip of the rocks at Poyelli is northward, and as such by its position, the conglomeratic band must be overlying the limestone and the slatey argillite, and underlying the felspathic quartzite. And if this bed were really sedimentary and basal, one should expect a larger number of pebbles of limestones and slates and none of the quartzites. But on the other hand, most of the apparent pebbles are those of the overlying quartzites and also those of the vein quartz which invades them. The presence of pebbles of tourmaline quartz schist and of vein quartz which are seen to be of intrusive material in the series would be inexplicable if the "conglomerate" had a true aqueous origin.

Apparent pebbles due to fracture and weathering.

It will be noted later that many of the quartzite outcrops are featured by being intersected with numerous quartz veins. These veins have a tendency, on being sheared, to assume a rounded form and when faulted in addition look exactly like a group of pebbles. Even the quartz veins traversing the granitic gneisses have in places become so and a very good instance of such was noticed in an exposure of a granitic gneiss ½ a mile S.-E. of Mahadeo, where a vein of milk-white quartz of about 6 inches wide has been broken up into three perfectly smooth roundish lumps looking for all purposes as if they are individual caught-up pebbles. Some of the outcrops of quartzites of this State have the tendency to split up into roundish blocks along curved joints and by subsequent shearing or by ordinary process of weathering

the harder portions stand out like pebbles in a finer grained schistose or distintegrated matrix (Plate 2, Fig. 2).

Matrix material resembles the altered porphyries.

I expect a similar thing to have happened here. The porphyry has intruded between the argillite bed and the bed of the felspathic quartzite. It has formed an intrusive breccia with the latter rock and due to the subsequent crushing of the whole series both the intruded and intruding rocks have assumed the rôle of pebbles wherever they have withstood crushing, the crushed finer altered phases playing the part of the matrix. The matrix is highly sericitic and siliceous and its slide B/99 resembles that of an extremely altered phase of the porphyry series, B/415. The aggregates of coarser lumps of quartzite pebbles I attribute to the splitting *in situ* and subsequent rounding of the incorporated or caught-up blocks of the felspathic quartzite. It is true that Dr. Blanford has noted the occurrence of limestones and also granites[24] in some of the conglomerates further south of this area but I presume these to be in the zone where the granite itself has intruded the series and subsequently got crushed along with its various incorporated xenoliths. It is unnecessary to dilate on other minor points and on the whole this band of "conglomerate" of Poyelli appears to me more to be a modified intrusive breccia than a true basal sedimentary conglomerate.

Quartzites.

General characters.

This "conglomeratic" band is succeeded to the north by a more homogeneous finer grained felspathic quartzite of variable colour of pale mauve, bluish grey, pinkish, etc., the colour being local and not traceable either across or along the strike of the beds. This quartzite or quartzitic sandstone is distinctly bedded and the one forming the southern scarp face of the △ 793 precipice shows here and there well-preserved patches of ripple marks. These beds are intersected with white vein quartz, portions of which when crushed look not unlike some of the quartzites of the region. The following representative specimens of this felspathic quartzite will illustrate its character.

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[24] W. T. Blanford, *Op. cit.*, *Mem. G.S.I.*, Vol. VI, p. 41.

B/419. Fine textured purplish felspathic quartzite or grit. In microsection (Plate 15, Fig. 4) this shows

Micro-characters. clastic grains of quartz of variable dimensions almost clear, a few small crystals of multiple twinned plagioclase mostly clear, some broken and with worn edges, microcline, and a few crystals of blue or pink tourmaline as small grains and prisms and also of somewhat larger patches. The quartz grains and felspars are cemented with sericitized siliceous portions. (Compare with the slide of Alwar grits, *Mem. G.S.I.*, Vol. 45, Pl. 15, Fig. 1.)

B/420. Similar to the above in general appearance; here the coarser grains of quartz and felspar have been separated by an apparent cementing material of a confused aggregate of granular quartz, chlorite and sericite. Some of the quartz crystals have been granulated and have a secondary deposition of silica around them. Many of the felspar crystals are sericitized. A few grains of violetish or purplish pink tourmaline are noticeable (Plate 16, Fig. 1).

B/421. Softer pinkish grey quartzite:—In texture this is similar to B/419. Though the majority of the grains show their edges smoothened, there are a few which have got angular or jagged borders. This is due to the secondary deposition of silica around the original contours of the grains. Felspars are not noticeable. Tourmaline occurs sparingly as small olive green grains. Cementing material is sericitic.

B/422. Pinkish grey vitreous quartzite:—The microsection of this shows fairly coarse rounded grains of quartz and completely sericitized worn rods and grains of felspar cemented with fine granular quartz (Plate 16, Fig. 2).

None of these slides show any evidence of severe crushing excepting perhaps some grains of quartz which show an undulose extinction.

To the north, this felspathic quartzite is succeeded by a band of soft, dark grey gritty quartzitic rock containing grains and patches of magnetite. This under the microscope appears to be a highly altered finer phase of the porphyry series (B/415-418) already noted. This in turn is succeeded to the north by bands of harsh vitreous quartzite mottled pink and white in places, forming the

northern scarp of the Poyelli ridge. This has been faulted often along its strike with a downthrow to the north and the fault scarp presents an impressive sight from a point immediately N.-E. of the waterfall. Closely associated with this are indefinite bands of gritty conglomeratic rocks in which there is scarcely any striking difference between the matrix and the pebbles, the whole consisting of rounded particles of quartz of different dimensions, some being distinctly opaline blue, as in B/96.

Summary of the characteristics of the Poyelli rocks.

By this brief description of the individual components which constitute the Champaner beds (or the Poyelli group) it is clear that there are rocks which show the characteristics of true sediments mixed up with those which are distinctly igneous and with others of doubtful origin. The ripple marked felspathic quartzite, and the slatey argillite I take to be originally sedimentary. The sericitized siliceous schists with blebs of opalescent quartz are traceable as extremely altered phases of the porphyry dyke and are thus evidently igneous in origin. The true mode of origin of the limestone on account of its considerable metamorphism is not beyond a shadow of doubt, but still I presume that to have been primarily of aqueous origin.

The porphyry has intruded between the slatey argillite and the felspathic quartzite and *lit-par-lit* fashion between the bedding planes of the latter itself. But it does not seem to have produced any marked changes in the invaded rocks. The argillite has developed a slatey cleavage probably as a result of this intrusion but no new minerals have been developed in that. The sandstone has become quartzitic and has got extra the minerals tourmaline and some felspar from the porphyry. The size of this porphyry appears to be too small to have produced the marked development of the secondary minerals in the limestone. This extreme alteration of the limestone may perhaps be due to an underlying concealed sheet of granite, an extension of that outcropping near Chelavad. The conglomerate evidently is autoclastic, the assemblage of apparent pebbles depending upon the zone of intrusion and the nature of the intrusive. Briefly then the Poyelli group of Champaner series of this region may be said to consist of quartzitic sandstones and grits, argillite, and limestone invaded by the porphyry and presumed granite. The

following sketch gives an idea of the general distribution of these rock types in the Poyelli region (Fig. 2).

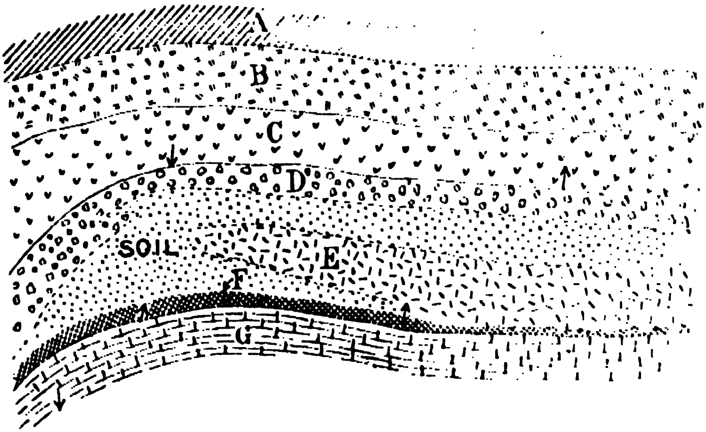

Fig. 2.

A. Rajgad Shales.	**C. Felspathic quartzite.**	**E. Porphyry.**
B. Brittle quartzite.	**D. Conglomerate.**	**F. Slatey argillite.**
	G. Limestone.	

B. The Dharia Limestone.

General characters.

Immediately to the north of the harsh mottled quartzite of the Poyelli scarp, at its western end is a thin series of greyish white crystalline limestone associated with calcareous grit and brownish micaceous calciferous grit, exposed locally here and there. The westernmost exposure of this was seen forming the low ridges to the north of Dharia wherefrom the limestone continues eastwards and passing through the cutting in the railway line pursues for some distance on the northern flanks of the ridge north of △793 for about ½ a mile and is then lost, probably being faulted to the north. A very similar series of rocks of the same thickness (250-300 feet) is again seen on the low ridge ½ a mile S. of Pani on the northern skirts of the △1400 ridges which consist of quartzites. The limestone exposures near Dharia unlike the Poyelli outcrop are highly calciferous, well jointed and bedded and have not developed any secondary minerals. The exposure near Pani is dark grey, fine grained and granular and does not show any secondary minerals.

C. The Rajgad Shales.

Constituent types. To the north of this zone is a wide stretch of country consisting of argillaceous rocks, shales, phyllites, micaceous phyllites, and mica schists interbedded with thin runs of dark grey quartzite, dark grey hornstones, secondary amphibole rocks and bands of a dark grey granite porphyry. Owing to the predominance of shales in the series which are well exposed in the vicinity of Rajgad I describe them under the name of Rajgad shales.

Shales.

General characters. This shaly country presents a peculiar topography consisting of an innumerable number of steep ridgelets and mounds seldom more than 200 feet above the level of the plains (Plate 8, Fig. 2) intersected by numerous labyrinthine gulleys and winding creeks, the whole region looking from elevated spots from the west like a series of picturesque petrified waves. The argillitic rocks vary in colour from dark bluish grey to light blue, ash grey, greenish grey and muddy yellow. Signs of lamination are somewhat obscure in fresh exposures but they are generally accentuated on their weathered surfaces (B/73).

Bedding is distinctly noticeable at some of the places especially in the exposures along the Kharod River. Many of the types are shaly and are too soft for slicing.

Hornstones.

Macro- and Micro- characters. The intercalated beds of the hornstone types occur as distinct continuous bands in the shales quite conformable and parallel to their strike. They are of variable character being light to dark grey, compact, brittle and apparently structureless at some places, while at others as near Nathpura they are distinctly banded. This banding or lamination is due to a difference in colour, the bands consisting of lighter and darker portions and of micaceous or quartzose layers. The hornstones vary in texture from very fine compact types to slightly coarser varieties. The micro-sections of the several types, B/71, B/73 and B/76, all show scales and patches of reddish brown biotite, a fine grained (micro-crystalline) aggregate

of granular silica, and opaque cloudy patches of irresolvable material (Plate 17, Fig. 1). The weathered phases of these look like gritty micaceous schists, but otherwise they are dark grey cherty-looking rocks with a superficial crust of pale greenish grey colour. Near Padla, Dharamkhetar, Undwa and Jhendri, they are striking an account of their ribbed and fluted character. They occur here in bands of 2 to 6 feet amidst the weathered micaceous phyllites as semi-bouldery rudely jointed outcrops breaking into ellipsoidal or irregular cuboidal blocks. Signs of lamination and banding are more pronounced in them towards their edges nearing the micaceous phyllites than in the centre of the bands themselves. In the vicinity of Nathpura, that is in the stream bed between Wankod and Labdadhara their exposures show sometimes ellipsoidal structures, the ellipses varying from 3 to 18 inches in diameter, and where such have been scoured out cavities either empty, or partially filled with silica and chlorite, have been left behind. In some of the softer shaly or phyllitic outcrops this fine banding or lamination takes the form of concentric markings around a central nucleus like concretions (B/75). Somewhat similar structures seem to have been noticed also by Dr. Blanford in the Bijawar limestones.

Secondary Amphibole Rocks.

Association.

Associated with these hornstone types are occasionally found thin irregular bands of tough siliceous granulitic rocks with variable amounts of garnets and chloritised amphiboles. They are always thin, very tough, and are generally highly siliceous with a sprinkling of calciferous material and show matted aggregates of a dark amphibole crowded together usually at the surface.

Adepur outcrop.

On the S.-E. flanks of the hills △800 to the N.-W. of Adepur in association with the hornstone band is seen a thin run of such garnetiferous amphibole rock of about 6″ to 1′ wide traceable for a distance of about 100 feet beyond which it is lost amidst the debris. Further onwards the hornstone band continues and as elsewhere it shows here also a ribbed or fluted structure, the ribs forming thin laminæ of quartz being as many as 16–18 within the width of a foot. This rock is highly corrugated at the surface

and has developed superficially as a crust plenty of mica and pale green patches of amphibole (B/117). The slide of this specimen shows a confused mass of granular deep red brown biotite through which bluish green amphibole is scattered. Greyish granular sphene is found throughout. The base consists of fine granular silica. Associated with this there is a fine grained normal quartzitic sandstone (B/118) of about 1 to 1½ feet wide. The series shows here a distinct bedded appearance (Plate 9, Fig. 1). The contact between the ribbed zone of the secondary minerals and the dark grey hornstone portion is very sharp, the latter containing as elsewhere large ovoidal cavities. The mode of origin of these types which have got developed in them the secondary amphiboles, etc., merits a brief discussion and as they are developed to a larger extent in the next division, the Baria quartzites, it will be considered later.

Quartzites.

Northern boundary outcrops.

In addition to these main types which constitute the series of Rajgad shales, near the northern edges of the series are a number of bands of quartzites. These are of variable character, some resembling the vitreous dark grey bouldery types like those near Devgad Baria, and others which form the Pali hill, ⊙538 consisting of light cream and pink coloured soft gritty types resembling exactly the Champaner quartzites of the Poyeili region. Half way up this Pali hill one of the bands of this quartzite shows signs of current bedding and lamination. Unfortunately the outcrops of these quartzites are neither traceable continuously nor are they found in close association. To the south of Unchabeda and Ambakhunt forming the △830 hill ranges are again two bands of the dark grey quartzite garnetiferous in places.

Unchabeda outcrops.

Associated with the above quartzite near Unchabeda and behaving intrusively towards it is a run of a dark grey granite porphyry. This outcrops bouldery, and locks like a fine textured bouldery granitic rock showing rounded spots of felspar and biotite. Its slide, B/123, shows a porphyritic texture consisting of well-rounded phenccrysts of quartz and felspar mostly untwinned and biotite in a finer textured ground consisting of the same

minerals. There are also a few flakes of muscovite. Another band of similar rock approaching the type of a quartz porphyry (B/126) was seen further S.-E. in the nulla-bed near the State boundary about 3 furlongs E.-S.-E. of ⊙750. This on its weathered surfaces shows blebs of blue opalescent quartz. Along with the quartzites and shales, these also have been cut out by the coarse grained pegmatites which belong to the porphyritic granite series of the Haveli mahal which will be described later.

Pyroxene Rock.

A pale green fine grained compact granular pyroxene rock almost resembling those occurring in the archæan complex was found as lenses and bands amidst the dark micaceous schists and phyllites of this group in the western portion of the village Chhotra. Here the micaceous phyllites are traversed by pegmatites and intersected by milk-white quartz reefs. The type shows the same sort of colourless coarse plates and grains of pyroxene (diopside) and a fair amount of grey granular or pinkish brown sphene. Granular quartz, minute scales of talc, and some colourless epidote form the rest of the minerals. There are no hornblendic rocks in association.

Strike and dip.

The rocks of this series strike generally W.-N.-W. and when well exposed along the river sections or deep cuttings they show high angles of dip of 60° to 80°. Otherwise at the surface owing to minor crumplings the dips may be taken ranging anywhere from 30° to 60°.

Comparison with Poyelli group.

The Rajgad shales differ from the Poyelli group in the following respects. Petrologically the phyllitic schists of the Rajgad shales differ from those of the Poyelli group in having more of biotite and in the absence of sericite. Quartzites of this series occur only as thin dark grey intercalated bands. They are finer grained, argillitic and impure. Definite bands of limestones characteristic of the Poyelli group are not found among the Rajgad shales, nor are the hornstone types of this series found in the Poyelli group. The Rajgad shales have been folded into a broad syncline with minor crenulations resting on the harsh brittle quartzites. The Rajgad shales have been cut out to the east and north by the granitic rocks

of different series while to the west they are lost under alluvium and soil. The contact alterations produced in these will be dealt with later.

D. The Baria Quartzites.

Constituent types.

Separated from the Rajgad shales by a wide stretch of country of granitic rocks, the southern edge of the Baria Quartzites crops out in the vicinity of Devgad Baria from about a mile south of the Panam River. Since nearly a half of the State consists of the members of this series which are well developed in the central and northern mahals and as quartzites form the predominating members of the series I refer to this group as the " Baria Quartzites ". The series consist for the most part of typical quartzites of dark bluish grey, light bluish, greenish, pinkish grey, and pink coloured types, variable in colour from point to point but all having a common characteristic of being brittle, jointed and highly fissured.

The quartzites are interbedded with a series of fine grained gritty flakey micaceous schists with thin intercalated bands of siliceous amphibole rocks. Among the flakey micaceous schists are in places thin intrusive tongues of a highly crushed gritty micaceous granitic gneiss which so greatly resemble the true mica schists that at times it is difficult to separate the two. This is especially so in the Devgad valley.

Quartzites.

In the vicinity of Devgad Baria the quartzites show a N.-W. strike with a general N.-E. dip of 50°—60° and traced further they gradually swerve N.-E. and then almost E.-N.-E. bending into a complete arch disappearing to the east under the Deccan Trap. In the latter zone they have their summits levelled forming wide apparently horizontal expanses, where they show relicts of sedimentary structures.

Mode of disposition.

In many cases it is difficult to find out the true magnitude of dips of the quartzites and very often even their general directions of strike are not very clear. Near Edalwara and Nagpur they form steep scarps to the east and pronounced dip slopes to the west. Near Devgad Baria and in the western parts of Randhikpur mahal they

form long chains of hog-backed hills. In central parts of the Randhikpur mahal they have been acutely folded into pitching anticlines and synclines and near Sanjeli they are thrown also into wide basin-shaped folds. In the eastern portion of the Randhikpur and Dudhia mahals these quartzites form flat topped wide plateaus with steep precipitous sides. The disposition of the joints and the differential weathering of the quartzites in the latter region have given rise to deep gorges of acute "V" and reversed "C" shapes through which the streams Hadap, Koliari and Kabutri have cut their channels. Occasionally the quartzites have weathered into conical hills and also into huge columnar monoliths (Plate 3, Fig. 2) as near Mander.

General Micro-characters.

Despite these differences in their structure and appearance the micro-sections of all these various types are very uniform in their mineral constituents and texture, consisting for the most part of rounded or rarely sub-angular grains of quartz with subordinate amounts of pale pink garnets, epidote, calcite, etc., developed locally under different circumstances as products of re-crystallization of impurities.

TYPICAL EXPOSURES.

General character.

The Devgad Region:—The conspicuous chain of hills running N.-W. towards the Devgad hill △ 1149, starting from near the junction of the Panam with its tributary stream 3 miles S.-E. of Devgad Baria, consists of this quartzite. In fact the series commences from about a mile south of the Panam and runs N.-W. bounding the northern and north-eastern edge of the porphyritic granite. In the road cuttings through the ridges to the south of Devgad Baria the quartzite bands show a strike of E.-S.-E. dipping 50° to 60° E.-N.-E. The bands are variable in colour, some being light grey and mottled with lilac patches. Now and then the quartzites alternate with thin bands of dirty greenish to light grey phyllitic micaceous schists. It is here the series gives a bedded appearance. A better instance of such is noticeable in the bed of the tributary stream which joins the Panam to the west of Jhabia, at the place about 2 furlongs N.-E. of the point of confluence. Here over a width of about 200 yards a number of parallel bands or beds of quartzite of about 3–4 feet wide are found parted by thin layers of

micaceous schist of 6–9 inches wide. Both the quartzites and the micaceous schists are traversed by veins of milk-white quartz varying in width from a fraction of an inch to 3 to 4 feet. In the vicinity of Devgad the outcrops of the quartzites which form the chains of ridges are somewhat irregular. This is probably due to the invasion of a tongue of granitic rock from one or the other of the southern granitic series which splitting asunder the original compact zone of quartzites has now converted that into the detached ranges of hills surrounding the present pear-shaped Devgad valley. The chains of ridges to the south of Devgad Baria run N.-W. parallel to the course of the Panam River for a distance of about 7 or 8 miles and then swerve N.-E., get split up into 2 groups the one continuing N.-N.-E. forming the westernmost chains of hills of the Randhikpur mahal and the other proceeding E.-N.-E. up to the south of Kaliakota where it suddenly bulges into wide plateau-like expanses forming a very characteristic topography. The top portions of these latter hills expose a series of quartzites with a predominating pinkish colour, but in general characteristics not unlike the rest of the quartzites.

Colour.

The specimens seen in these different outcrops vary from bluish to pale greenish grey or light grey to pinkish grey and pink. Excepting the last which seems to characterise a zone not far from the edges of the Deccan Trap, the rest of the colours are all local, diffused and superficial. In most instances they are due to imperfect reflections from the re-crystallized coloured silicates the rocks contain.

Micro-characters.

The micro-sections of most of these specimens show granular quartz fine to medium textured, mostly rounded and some with marginal re-crystallization, and a fair amount of impure dust mixed up with grains of iron-oxides. Granular greyish epidote, blue green chlorite, scaly sericite and garnet are noticeable in some of the exposures in the vicinity of Devgad Baria and elsewhere (B/5, B/6 and B/8). That the presence of these silicates is due to re-crystallization of impurities as effects of contact alteration has only to be surmised in many instances, but clearer indications of such having taken place near the contacts of the quartzites with recognizable igneous intrusives are also forthcoming which will be dealt with shortly.

Nalu-Edalwara Range :—Bounding on the west the coarse micaceous gneiss of the Dhanpur valley, the Kundawara-Nalu-Edalwara range of hills constitute another group of outcrops of harsh, brittle and granular quartzite varying in colour from bluish and greenish grey to pale pinkish grey. To the S.-W. of Kundawara the outcrop has developed well-marked system of dip joints intersected by a few prominent gash joints (Plate 5, Fig. 1). The general direction of outcrop here curves into a broad " S ". Further north to the west of Nalu and Edalwara the quartzite is intersected by a number of veins and stringers of quartz varying from a fraction of an inch to a foot or more in width. To the west of Edalwara the quartzite forms a double chain of ridges intercalated by a thin zone of micaceous schist. The eastern ridge, △ 1357, shows a dip slope to the west, and is absolutely bare of vegetation. The quartzite has weathered here into a sort of peculiar columnar buttresses giving rise to exfoliated roundish lumps and masses (Ptate 3, Fig. 1). Proceeding northwards, these scarps and hog-backed chains of hills merge into wide plateaus with steep precipitous sides. The levelled summits of these plateaus are again being carved by the present-day denuding agencies. These latter types of hills send out side spurs to the east like the apophyses from an igneous mass, but the specimens from such show that they are in no way different to the rest of the quartzites. The quartzites of this region are all jointed E.-N.-E. and the tongue-like projections of spurs are due to this jointing and differential weathering wherein the softer micaceous schists being scoured out have left the harder ribs of quartzite in that manner.

Field characters.

To the north of Chorbaria the summits of the lines of the steep ridges form as stated above wide flat expanses and these ridges continue maintaining that character eastwards to the north of Umria for a distance of 6 to 7 miles where they disappear under the Deccan Trap. Strike faults and local faults transverse to the line of strike combined with denudation has converted this zone into a maze of steep precipitous wall-like masses with intervening horizontal or transverse gorges, through the latter of which the river Hadap flows in its winding channels. The dislocated

Physiographic features.

blocks show triangular facets very well. The quartzites of this zone are harsh, brittle and massive, irregularly jointed and do not show any distinct signs of bedding (Plate 4, Fig. 1) but on the top portions of these massive blocks of quartzites are occasionally found small disjointed portions showing signs of ripple marks.

Parallel to the Nalu-Edalwara range about 3 miles further west is another chain of ridges consisting of a series of similar quartzites. The easternmost ridge of this part, △995, consists of bands of quartzite, mottled pink and grey. Here they outcrop north and south and as they are absolutely bouldery at surface do not show any well-pronounced dips. But about a mile west, in the bend of the stream where it flows north and south to the S.-E. of △1070, there are good exposures of these quartzites where they occur distinctly bedded over a width of nearly ½ a mile separated by thin intercalations of micaceous schists of varying thickness. Sometimes the micaceous schist occurs as a thin parting or filmy coat on the quartzite along its bedding planes, at others it varies in thickness from 10 to 20 feet when generally scoured out by weathering it leaves only gaping fissures. The quartzite here is dark blue grey weathering into a white thin surface crust. It strikes at this point N.-W. and shows a definite dip of 45° N.-E. It breaks as usual with a sub-conchoidal fracture and weathers bouldery. These outcrops continue westwards up to Ruabari and then swerve suddenly northwards and N.-E. But the bands further west forming the △1070 and △1013 chains of ridges continue westwards for a distance of 6 miles forming the chains of hills to the north of Devgad valley, whereonwards they bend back and turn eastwards like the rest of the exposures.

Pink Quartzites.

Extending from the western borders of the Deccan Trap for a width of 3 to 4 miles in the Dudhia and Randhikpur mahals is a zone of quartzites of a predominating pinkish hue, varying in tints from deep pinkish brown to pink and pale pink, cream coloured and pinkish white. Where the outcrops of these assume a ridge-like character, such ridges, as usual here, run eastwards beneath the Deccan Trap, but as near Chapri and Mander where they build up level, wide plateau-like expanses no definite directions of strike are perceivable. These plateau outcrops, to the west where

cut by deep channels show right through to their bottom the harsh vitreous brittle quartzite. Despite their predominating pink colour quite distinct to that of the rest of the quartzites in other parts of the series, yet as a whole these types are not separated from the others by any distinct stratigraphic break or definite unconformity. It is true that at the present base of these plateaus, here and there and especially along the stream bed to the south of Mander are found types of rocks which when removed from their setting might pass at first sight for conglomerates (B/288). But here again there is absolutely no difference between the somewhat rounded pebble-like protruberances and the rest of the flat base both of which consist of the same sort of quartzite in different stages of disintegration. On the top of the hill east of Mander different stages of the breaking up of these quartzites into the pseudo-conglomeratic lumps and masses could be studied.

They do not differ in any way from the rest of the quartzites in their texture, structure or general character. The colour seems to be due mainly to the hydration of the iron oxide which the quartzites had originally contained or acquired later. At some points due to the elimination of impurities and the cementation of the quartz grains with the deep red hæmatite the types, (B 288) taken from an inlier ½ mile east of △1291, show a striking resemblance to a sandstone, but otherwise the normal characters of the pink quartzites are the same as those of the rest of the quartzites.

The levelled plateau-like character of these pink quartzites is very conspicuous at the eastern borders of the State near their junctions with the cretaceous Deccan Traps. But proceeding westwards away from the cretaceous rocks this levelling of the summits of hills becomes gradually less and less pronounced until at a distance of about 5 or 6 miles from them the levelled character entirely ceases. Perhaps this base-level of erosion represents the land surface as it existed before the formation of the Lametas of this region. It has been upraised and is now being re-denuded. In this connection it is interesting to note that similar planing of the tops of quartzite hills of the same age has been observed both by Dr. Heron in the Rajputana area (*Mem. G.S.I.*, Vol. LXV, page 8) and by Mr. Middlemiss in the Idar State.

It is impossible to establish any definite order of sequence among these quartzites persistently over large areas. As a rule the dark grey quartzite seems to be the lowest member succeeded by the light bluish to greenish grey types which pass upwards into pinkish grey and pink coloured types. The hog-backed chains of hills are built up by the darker coloured quartzites while the plateaus characterise the pink variants.

About 50—60 specimens of these quartzites from different localities have been sliced and examined under the microscope. As a rule those far away from the edges of the granite consist mostly of quartz grains with interstitial crystalline aggregates of fine grained silica and some opaque cloudy patches. The quartz grains are generally rounded, dusty and impure, a few abraded or scratched and rarely clear. The quartzites in the Randhikpur mahal, of both pink and dark grey varieties, have small blebs of opaline dark grey to bluish grains which are noticeably honey yellow in sections. Magnetite grains are found to a small extent in the dark coloured types while the pink ones show variable amounts of deep red hæmatite either scattered irregularly, in streaks and patches or in some cases, though rarely, forming a definite cementing matrix. Those not far from the edges of the granites have in addition, epidote, calcite, zoisite, zircon and garnets and very rarely tourmaline. A general impression of the usual texture of the slides of these rocks can be gathered from the photomicrographs of some of the slides (Plate 18).

Micaceous Schists.

Variations.

Interbanded with these quartzites are micaceous schists of variable character, rarely exposed in outcrops sufficiently fresh to be sliced and studied in detail. They occupy the valleys intervening between the quartzite ridges, and are generally the portions which are under cultivation. Exposures are few and far, and have to be sought for in the nulla courses or in wells and cuttings. The types vary from place to place, such variations depending upon the surface colour, the habit and proportion of mica, the presence or absence of calciferous material and so on. As these variations cannot be traced continuously it is often difficult to determine whether the different looking types are the local modifications of

the same band or not. These rocks as their name implies are well foliated, and as in the quartzites, their bedded character becomes apparent only when they are intercalated with runs of quartzites. The quartzitic bands among these micaceous schists are usually thin, seldom more than 1 to 2 feet, finer grained, highly impure and argillitic but still in their external appearance do not differ in any way from the typical quartzites already described. The characteristics of the several outcrops may be briefly described under the following:—

Devgad valley exposures.
Nagpur valley exposures.
Dudhia mahal exposures.
Borkota exposures.

Devgad Valley Exposures:—Devgad Baria stands on the S.-W. corner of the pear-shaped valley which extends from the Devgad-Piplod road E.-S.-E. for about 6 miles with a general width of about 3 to 4 miles. The whole of this valley consists of a series of micaceous schists varying from light grey to yellowish green, and highly weathered muddy looking micaceous phyllites or schists irregularly jointed and interbanded with thin beds of fine grained impure granular argillitic quartzite both traversed by a number of veins of quartz. The somewhat fresher specimens show scales of light coloured silvery white sericite in the vicinity of the town, but in the other exposures this is rather rare, the type being a gritty biotite schist showing acicular or scaly crystals of black biotite. The chips obtained from a borehole which had been sunk in the northern portion of the bed of the Devgad tank show the micaceous rock to be a thoroughly crystalline dark grey siliceous schist having thin flakes of shining black mica. The slide of this specimen (B/14) shows scales and flakes of deep brown biotite and schistose aggregates of fine grained quartz without any distinct crystals of felspar. There are also a few larger patches and grains of quartz not well rounded. Magnetite and a few crystals of perfectly rounded garnets are noticeable. The slides of some other specimens (B/2, B/4 and B/13) show the same constituents, with slight variations in texture. Biotite has been partly chloritised. The interbanding or bedding of these micaceous schists with the quartzites is well seen in the section of the tributary river

which joins the Panam from the south about a mile west of Wandar. At the southern extremity of the exposure there are intercalations of highly micaceous schists in the quartzites followed by a solid mass of bedded quartzite for about 250 feet overlain again by micaceous schists thinly bedded and exposed for nearly 3 to 4 furlongs along that river bank.

Nagpur Valley Exposures:—Exposed here and there along the river channels in the valley between the Nalu-Edalwara quartzite hills and the eastern chains of quartzite ridges of the Devgad valley, are the same sort of gritty acicular micaceous schists, on an average somewhat coarser than those in the Devgad valley. These also have the same mineral constituents as the others. In these two areas the quartzites and the micaceous schists form wide zones, the quartzite forming ridges averaging 1 to 1½ miles wide and the schists the intervening valleys of about 3 to 4 miles.

Dudhia Mahal Exposures:—But to the N.-E. of these areas in parts of Dudhia and Umria mahals, the ground forms gently undulating or rolling downs in which are seen a number of parallel bars of bouldery quartzites alternating with the gritty micaceous schists. The quartzites are here more micaceous and the mica schists themselves more siliceous and in fact one passes into the other. In the vicinity of the trap region, the micaceous schists have been weathered into a soft gritty clay.

Borkota Exposures:—Further N. and N.-W. in the Randhikpur mahal the quartzites again become prominent forming conspicuous chains of ridges the intervening valleys consisting of micaceous schists, some being fine grained and acicular like those of the Devgad valley and others coarser resembling somewhat the types of micaceous rocks of the Dhanpur schists to be described shortly. Some of these types are calcareous, the one (B/361) got from a well near Singavad hospital showing in section a fine grained granular ground of carbonates and silica in which are seen larger platey crystals of honey yellow biotite and chlorite. The specimens from the other exposures of this area (B/357, B/365, B/366, etc.) show the same sort of black or bronzy mica in a gritty siliceous ground.

Secondary Amphibole Rocks.

In these micaceous schists to the N.-E. of Devgad Baria and also near Merap and Dahikote, there are a number of thin very tough bands of a siliceous granulite containing variable proportions of garnets, amphiboles and calcite. These are never traceable as distinct bands or beds persistently for any long distance. Since names like the hornblende granulite or garnetiferous hornblende granulite are likely to cause an impression of the types under consideration being similar in origin and appearance to those well-known granulite types, I refer to these dubious rocks by an indefinite name of secondary amphibole rocks for descriptive purposes here. These vary from a fraction of an inch in thickness forming only a surface crust along the bedding planes of quartzite to definite layers or bands of about a foot in thickness. They are usually parallel to the strike of foliation of the schists and it is only at one spot near Labdadhara among the Rajgad shales, a similar rock was found to slightly meander across the bedding planes of the phyllitic schists.

Mode of occurrence.

Among the Rajgad shales these secondary amphibole rocks are noticeable as thin runs in association with the cherty hornstones at or very near their contacts with the micaceous phyllites. In the Baria quartzites and the Dhanpur schists they occur as thin bands in the micaceous schists at or near their junctions with the larger bands of quartzites. Field evidences clearly point out that these amphiboles with their usual associate the pinkish garnet are entirely secondary formed in the series as a result of metamorphism of either impure argillaceous layers in the quartzites or of somewhat thicker bands and lenses of calc-argillaceous material in such. In the former instances the minerals are noticeable in the superficial portions of the quartzite either dotted irregularly or forming a thin surface crust, and in the latter the secondary rock forms tough bands in the series.

The following descriptions of a few of the typical localities will indicate this :—

About 3—4 furlongs N.-N.-W. of Ratadia on the eastern side of a small nulla joining the Panam is an exposure of bouldery

dark grey brittle quartzite cut out by an indistinct exposure of a micaceous pegmatite. This is at the edge of the quartzite series and probably the granitic gneiss extends beneath it laterally, sending above these tongues of pegmatite. The type taken close to the pegmatite is a light grey vitreous siliceous rock dotted with pale pink garnets and green minerals (B/15). The slide of this shows rounded to sub-angular grains of quartz, calcite, pale pink garnet, bluish green chlorite, chloritised amphibole and sphene, the latter enclosed in the amphibole crystals. Another specimen (B/16) obtained from a few feet further east near the contact shows larger crystals of sub-angular quartz mixed up with finer granular aggregates of the same and contains more of amphibole than chlorite, and greyish granular sphene with dots of ilmenite kernels. Calcite has almost disappeared but garnet is noticeable. The normal type (B/17) taken some distance away from the contact shows none of the secondary minerals seen in the above two specimens. In its texture it resembles the above, and shows sub-angular grains of quartz, dark brown scales and patches of biotite and lighter coloured sericite. A small quantity of chlorite, ilmenite and carbonate dust are noticeable. It is evident here that due to interaction and recrystallization of the impurities garnets and amphiboles have been secondarily formed.

Ratadia exposures.

In the nulla to the east of Dangaria (about 3 miles N.-E. of Devgad Baria), the micaceous schist has a number of widely spaced thin vein-like bands of a tough siliceous rock showing matted blades of dark amphibole. Owing to their weather-resisting nature they stand out like hard ribs in the softer weathered micaceous schist. In their vicinity the mica schist shows banding or apparent lamination consisting of lighter and darker layers. The lighter siliceous layers also have decomposed garnets. The slide of the amphibole rock (B/3) shows a fine grained aggregate of granular silica and calcite in which are scattered large prisms of chloritising amphibole perforated with granular quartz and calcite. The amphibole is highly pleochroic showing as usual blue, green and yellow colours for the principal directions of vibrations. On account of its extremely perforated character, cleavage lines are obliterated and the extinction angle cannot be measured accurately.

Dangaria outcrops.

But for its perforated character, the amphibole does not seem to differ from those seen in the true dark hornblendic schists of this State. Pale pink garnets and larger crystals of calcite and quartz are also noticeable. Similarly near Merap and Dahikote are seen a number of bands of this rock in the micaceous schists. Among the specimens selected as variable types of this rock from different outcrops it is possible to establish a gradational series ranging from a typical quartzite with mere specks of these secondary minerals to rocks which contain nearly a half of these in proportion as seen by the following:—

B/404. Grey quartzite with black spots of amphibole minerals not well differentiated.

B/52. Grey quartzite with pink garnets and amphibole dots.

B/283. White quartzite with black patches of amphibole and banded with ferruginous grit.

Gradational types.

B/3. Light bluish grey compact quartzite with a good deal of dark prisms and patches of amphibole.

B/332. Banded rock showing layers, siliceous and amphibolic.

B/302. Light pinkish grey quartzite with a fair amount of black amphibole.

At none of the spots wherefrom these specimens were taken is there any evidence to regard these types as igneous, as they never traverse across the strike of foliation of the micaceous schists, nor do they show any distinct textures of igneous rocks. Their position, in between the quartzites and the mica schists, and the well-pronounced banded character of the latter at such places indicate that there was a sorting of material. Probably such diverse laminæ have all been involved together in subsequent alterations, and the mineral amphibole might have secondarily developed in them as a result of static metamorphism.

Igneous Intrusives.

As an integral component of the Baria quartzite series are two outcrops of igneous intrusives, but this time basic in composition found in the vicinity of Kesarpur.

Just near the bend of the streamlet joining the Hadap River to the N.-E. of Kesarpur is an interesting exposure of a lenticular sill of dolerite which cuts across and includes long lenticular runs of the quartzite members. The basic rock is coarse grained, massive and is traversed by thin streaks of quartz and felspar-epidote veins. Round spheroidal lumps project from the mass, like knobs, and this gives a characteristic appearance to the rock. At its edges it is finer grained, slightly schistose and micaceous. Some of the quartz veins have granular augite and chlorite and they are probably the later acid differentiates of the dyke mass. Under the microscope the slide of the dyke (B/374) shows coarse prisms of purplish grey and purplish pink pyroxenes mostly fresh, bright bluish green amphibole partly chloritising, and felspar mostly altered. Some of the felspars are enclosed in the pyroxene crystals ophitically. Ilmenite is found in fairly large quantities. This rock does not resemble any of the coarser types among the Deccan Traps further east. It is doubtful whether it is a dyke phase of those trap flows, or an intrusive sill in the series of a distinctly earlier period.

On the northern bank of the river about 3 furlongs west of Kesarpur amidst highly decomposed kankary micaceous schist is a solid lenticular band of greyish green schisted hornblendic rock of about 1 foot wide. A little further west are found other thin bands of similar fine hornblendic schists for about 8 or 10 feet, followed by a solid stretch of micaceous schist for nearly 3 to 4 furlongs. This fine grained greyish green hornblendic schist has a few patches of a very coarse, dark, speckled hornblende granulite. Apart from such there is also a definite thin run of the coarser speckled rock. The microsection of this type (B/383) shows pale green amphibole in isolated slender blades or frayed coarser prisms and in radiating bundles. The salic minerals consist of fine granular quartz, colourless epidote and grey spongy and granular sphene. Felspars are not clearly recognizable. This rock is schisted just like the adjacent micaceous schists and it is doubtful how far it was originally igneous or sedimentary. In general appearance and microsections the type resembles the eruptive hornblende schists in association with the rocks of the upper division of the Dharwars of Mysore.

The Baria quartzites have been intruded by the porphyritic granites of the Haveli mahal both at their southern and western edges. About a mile W.-N.-W. of Bayana are found a number of disconnected bands of quartzites as inclusions in the marginal zone of the porphyritic granite. Further east about a mile to the N.-W. of Simalakasi the pegmatites of the porphyritic granite series have broken across, cut out and included oval patches of the quartzites as seen below (Text Fig. 3).

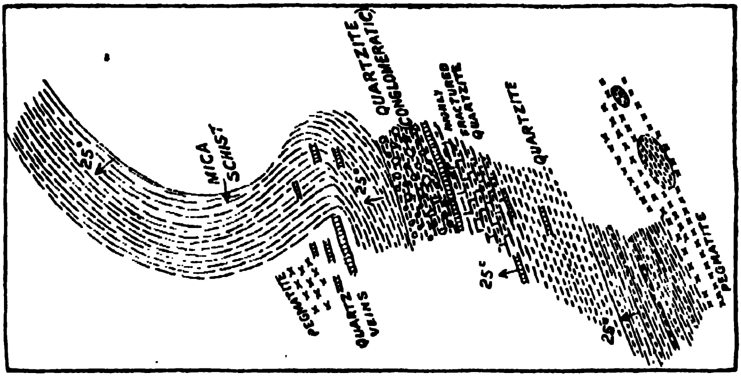

Fig. 3.

To the N.-W. of Ratadia the production of amphibole and garnet as minerals of contact metamorphism due to the intrusion of pegmatite has already been noted. Similarly a little to the north of the 9th mile-stone in the Godhra-Rutlam road, at the edges of the series the quartzites have been traversed across and cut into strips by the pegmatites and they have also developed garnets and tourmaline as the result of such intrusion.

E. The Dhanpur Schists.

The rocks of this series constitute the sillimanite quartzite, the coarse grained foliated dark grey biotite micaceous gneisses and thin runs of dark grey compact quartzite passing upwards into a thin series of bedded friable quartzites.

Distribution. The members of this group unlike those of the Rajgad shales are more crystalline though they show comparatively lower angles of dip. They are found confined to the low ridges and the valley floor between the

western flanks of the plateau hills of Jhabu and the long steep ridges of the Nalu-Edalwara ranges, and to the south they are in immediate contact with the biotite gneisses of the archæan complex of the Khalta valley. They are again seen forming the lower ground to the east of the Jhabu plateau. Both in their eastern and western extremities the series show a general N.-N.-W. to N.-W. strike with dip angles of about 40° to 45° but where they approach the plateau region their strikes and dips are quite irregular. At their southern extremity the rocks have a general E.-N.-E. trend following the irregular line of contact of the biotite gneiss.

Relationship with the archæans doubtful.

The lowest member of the series is a highly foliated crystalline micaceous gneiss which forms all the valley floor of the region. At the southern border it is not well exposed being hemmed in as it were between the biotite granitic gneiss and the sillimanite quartzite ridges, and shows only obscure outcrops here and there amidst the debris of the sillimanite quartzites. It rests directly on the uneven edges of the biotite granitic gneiss and at times it becomes doubtful whether this indented contact is due to the micaceous gneiss resting unconformably on the upturned and eroded edges of the granitic gneiss or due to an eruptive unconformity, the result of the granitic intrusion. I favour the latter view as there is no conglomerate at the base of the micaceous gneiss. Besides, this micaceous gneiss has developed garnets and sillimanite here and there along the line of contact and even the overlying gritty micaceous quartzites have developed sillimanite which I attribute to the effects of contact metamorphism. In all probability the basement beds of these Dhanpur schists have been intruded by the biotite granite of the Khalta valley and their southern edge being cut out is enclosed now as a long strip of inclusion with an apparent direction of W.-N.-W. following the line of contact of the granitic gneiss. Later crustal disturbances possibly prior to the eruption of the Deccan Trap have severely folded the pliable Dhanpur schists producing in them a foliated structure and a crystalline texture. It is possible that the edges of the biotite granite have also suffered the same disturbance along with the Dhanpur rocks wherein the original granite has become foliated and gneissic assuming almost a similarity of appearance to the micaceous gneiss.

It is often difficult to place the exact boundary between the biotite granitic gneiss and the metamorphosed micaceous gneiss, but generally the zone of granitic gneiss is intersected by a number of pegmatites and aplites which are not found in the zone of the micaceous gneiss, besides the granitic gneiss even in its extreme stage of crushing shows almost always platey crystals of felspar which are not seen in the micaceous gneiss.

General characters of micaceous gneiss.

Bedding and stratification have been obliterated to a large extent in the lowest zones of these micaceous gneisses, on the other hand they show well pronounced strike and dip of foliation. In appearance they are fine to medium grained, compact dark grey crystalline rocks showing small plates of shining black biotite and occasionally pink grains of garnet. The microsections of the unweathered forms show a schistose aggregate of granular quartz and mica in which are seen scattered large plates of deep honey brown biotite, patches of green amphibole (B/179, B/189, B 180) and scales of colourless mica. Sphene is noticeable in B/180, and pale pink garnets in B 189, and B 24. Sillimanite is seen very occasionally and one of the specimens shows also some andalucite (?) (B/265). In their upper zones, they are highly weathered, softer and look like silvery white micaceous phyllites, but the slides of these differ from the darker crystalline types only in containing a little more of colourless mica.

Overlying the micaceous gneiss to the west of Khalta valley are thin bedded coarse micaceous grits and sillimanite quartzites forming the Δ1475 range of hills. These are exposed for the most part in the adjoining Rattanmahal State and only the eastern extremity of the series comes within the Baria State. To the south of Ladiawad where the Khalta River makes a northerly bend the exposures show quite distinctly signs of lamination and bedding (Plate 6, Fig. 2). The lowest member not far from the edge of the granitic gneiss, is a light grey micaceous gritty schist showing small dark or greenish spots. The slide of this shows a granular aggregate of rounded quartz, dark reddish brown mica, garnet and fibrous bundles of sillimanite. Felspars are not noticeable. This bed passes upwards into more quartzose types containing sillimanite and sericite (B/162 and B/163). Colourless garnets are also noticeable in these here and there.

The valley regions in the Dhanpur mahal consist of the micaceous gneiss interbedded with thin bands of highly weathered fine textured micaceous quartzite. Towards the east approaching the Jhabu plateau the micaceous gneisses or their variants the sericitic phyllites are highly folded with frequent variations of strikes and reversals of dips. In places they are overlaid by a thin series of bedded dark grey brittle quartzite, not unlike those of the Baria quartzites. These in turn pass upwards into a thin series of highly friable micaceous quartzites which form the chain of ridges running W.-N.-W. from Δ1548, and another parallel ridge to the south of Holkadhar. These quartzites do not occupy any large extent of ground.

Quartzites.

The dark grey brittle quartzite has the peculiarity of breaking up in the mass into rounded lumps of varying sizes depending upon the curvature and closeness of joints. This sort of structure with a differentiation into apparent pebbles and pseudo-matrix might pass for a regular conglomerate in obscure exposures which cannot be closely studied. A very good instance of such is seen in the exposure in the north and south running branch nulla near the source of the Walwa River where the outcrop is finely fissured into rude polygonal blocks. The harder portions are again broken up into smaller lumps so that in a mass of homogeneous fine grained apparent matrix a group of pseudo-pebbles have stuck out (Plate 2, Fig. 2). At this spot the vein quartz also has been sheared, faulted, and rounded off into pseudo-pebbles.

The slides of the grey brittle quartzites corresponding to similar types among the Baria quartzites, show granular quartz, epidote, chlorite, calcite and garnet in small quantities (B/202 and B/186). The slides of the friable quartzites are in no way different to those of the normal Baria quartzites in their texture, but contain more of mica.

Secondary amphibole rock.

Thin layers or bands of siliceous rocks with garnets and amphibole similar to those described as secondary amphibole rocks among the Baria quartzites are also rarely found among the micaceous gneisses of the Dhanpur schists. The micaceous gneisses, like the Rajgad shales and Baria quartzites, are intersected with a number of veins of white quartz.

Summarised Comparative Characteristics of the Champaner Sub-groups.

A *resumé* of the chief characteristics of the five groups described as constituting the Champaner series will show, that the Poyelli beds have distinct bands of magnesian limestones which are not found in the others. Of the conglomerates, the well-developed exposure of the Poyelli region has been suggested to have had an autoclastic origin. Some of the types of the Baria quartzites have also been noted to break actually *in situ* into rounded lumps to form a pseudo-conglomerate. Among the Rajgad shales and Dhanpur schists conglomeratic structures are uncommon.

Among the Poyelli beds, some of the quartzites, and slaty schists show distinct signs of sedimentation. The associated limestone is highly metamorphosed rendering it difficult to ascertain its origin. True igneous intrusives also are mixed up in the group, which when highly crushed get perfectly schistose simulating in appearance the schistose phases of recognizable sedimentary bands.

The Rajgad shales show better preserved signs of sedimentation and bedding though they have also got their structures obliterated at many parts due to dynamic and contact alterations. They are also intruded by granite porphyry and quartz porphyry rocks. For the most part the series consists of argillitic and shaley material with thin intercalated beds of hornstones and quartzites.

The Baria quartzites as their name implies are essentially quartzites with intercalated beds of micaceous phyllites and mica schists. In most of the exposures the original structures have been entirely obliterated. The rocks are cut by numerous horizontal and vertical joints in addition to other irregular cracks which render it difficult now to recognize any original planes of bedding if existing, but in the eastern zones where the series approach the plateau regions or the Deccan Trap, structures indicative of shallow water facies such as ripple marks and sun-cracks are noticeable (Plate 7, Figs. 1 and 2). Even here the rocks have been altered and rendered thoroughly crystalline, but the original structures have partially escaped destruction. Where the quartzites are found intercalated with the phyllitic micaceous schists signs of bedding are promiscuously seen (Plate 6, Fig. 1).

Granite porphyry and quartz porphyry dykes similar to those noticed in the other groups are not seen among the Baria quartzites, but near Kesarpur the quartzites have a lenticular intrusion of a porphyritic dolerite of probably the Deccan Trap age, and thin bands of pale greyish green hornblendic runs whose precise origin is doubtful.

The Dhanpur schists consist for the most part of a coarse textured micaceous gneiss or micaceous hornblendic gneiss intercalated with beds of highly friable apparently bedded micaceous quartzites at its top. The friable nature of the quartzite is probably due to the effects of hydration and alteration associated with the outpouring of the Deccan Trap flows.

None of these groups are marked by any true basal conglomerates. Owing to their uncertain directions of dips, the extreme alterations of structures they have undergone, the widely separated areas where each is individually developed it is difficult to establish with confidence any true sequence or stratigraphic relations among these several groups. In the Poyelli region the general direction of dip of the exposures is northwards. The extreme northern band of the harsh brittle quartzite of the Poyelli scarp which dips steeply to the north is in its texture not unlike that of the brittle greyish quartzite of the Δ663 ridge forming the northern border of the Rajgad shales. The quartzite of this outcrop is dipping south. If we can correlate the two widely separated exposures of these quartzites as of individual limbs of the folds of the same band, then the Rajgad shales may be regarded as resting on this band with a general synclinal fold occupying a higher horizon than the Poyelli beds. The lesser degree of metamorphism of the shaley members of this group corroborates this. To the north of the quartzite band there is a wide spread of granite. The members of the Baria quartzite bounding the granitic edge again dip northwards. And as those resemble in texture and character the Poyelli scarp outcrop and that of the Δ663 ridge, the quartzites may be regarded as being intruded by the granite along the southern limb of their anticlinal fold in which case the Baria quartzites must constitute the top portions of the Poyelli group, overlain by the Rajgad shales. The relations between the Dhanpur schists and the rest of the other groups are again not clear. The dark grey quartzite bands similar to those found in the vicinity of

Devgad Baria are found underlying in places the friable quartzites of the Dhanpur schists, but the coarse micaceous gneiss of the Dhanpur valley at its western edge dips under the quartzite bands of the Nalu-Edalwara Range of the Baria quartzite type. There are not sufficient grounds to assume any inversion of beds here. If the structure as found represents the true sequence then the micaceous gneisses of the Dhanpur schists must be older than the Baria quartzites, and if so whether they form the upper part of the archæan schists or the lowest horizon of the Champaner series is not evident. Tentatively then the Champaner series of this area may be classified as:—

Champaner series	Rajgad shales,	
	Dharia limestone,	
	Baria quartzites, Poyelli felspathic quartzite	
	.... conglomerate ...	(?)
	Poyelli limestone, argillite, etc.	
	Micaceous gneiss of Dhanpur (?)	
	....	(?)
	Archæan crystalline schists and gneisses.	

CHAPTER V.

Correlation of the Champaner Series.

I have already stated that Blanford who recognized the Champaner series in 1869 believed that it did not exactly correspond in its lithological characteristics to any other series or systems of "transition rocks" recognized till then. Subsequently relying on the recorded descriptions of these rocks Oldham[25] suggested that the series might correspond to the rocks of the Delhi system and Heron has also noted the probability of the Champaner beds being the nearest analogue of his Delhi system. (See footnote 1, p. 110, *Mem. G.S.I.*, Vol. LXV, *Op. cit.*) Bruce-Foote[26] seems to have thought that the equivalents of the Champaner beds must be looked for among the Cuddapah rather than the Dharwar deposits. Fermor[27] examining in 1905 the Champaner rocks near Sivarajpur found an extraordinary similarity between them and the crystalline schists near Jubbalpur which inclined him to regard the Champaner series as of Dharwar age. Beer[28] who mapped a fairly large portion of the Baria State and its adjacent parts, has taken for granted that the Champaners are the equivalents of the Dharwars. Wadia[29] has correlated the Champaner series with the Aravalli system regarding both as the equivalents of the South Indian Dharwars.

Hacket[30] who proposed originally the term Aravalli series to a series of quartzites, schistose conglomerates, hornblendic and micaceous schists, calciphyres and limestones, highly altered and full of secondary minerals, subsequently modified his views[31] and removed certain members of his original Aravallis as

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25 R. D. Oldham, *Manual of the Geology of India*, Chapter III, p. 73.

26 Do. do. do. p. 75.

27 L. L. Fermor, *Mem. of the Geol. Sur. of Ind.* Vol. XXXVII, Pt. 2, Chap. XIV, p. 282 and Pt. 4, Chap. XXX, p. 652

28 E. J. Beer, *Op. cit.*, p. 97.

29 D. N. Wadia, *Geology of India*, Chapter IV, p. 65.

30 C. A. Hacket, *Rec. of the Geol. Sur. of India*, Vol. X, pp. 84–85.

31 Do. do. Vol. XIV, p. 281.

of a distinct younger formation classifying them separately as "Delhi series". Heron[32] in a revision survey of the Aravalli area of Rajputana, reviewing the classifications of Hacket as originally proposed and subsequently modified divided the rocks into *two* distinct *systems*, *viz.*, the Aravalli and the Delhi systems, sub-dividing the latter into four groups or series adopting Hacket's original classification with slight modifications. His subsequent examination of other parts of Rajputana has led him to recognize the "Raialo series"[33] which he originally regarded as the lowest group of his Delhi system to be a distinct separate unit, like the Aravalli or the Delhi system being intermediate in age between the two. Middlemiss[34] surveying the Idar State a south-western continuation of the Aravalli range divided the pre-cambrian rocks of that State into the older system of Aravallis and later systems or series of the Delhi quartzites and the Phyllites.

The Aravallis of the Idar State are correlated by Mr. Middlemiss with the Archæans and the Delhi quartzites and the Phyllite series of that State are suggested by him to be "Purana". Recognizing the Aravallis as Archæan, Dr. Heron also classified his Delhi system of Rajputana as Purana suggesting it to be of probable Cuddapah age (*vide Mem. G. S. I.*, 45 already cited, pp. 110-111), but with what he would now correlate his Raialo series, I am not aware.

Thus the types and series of rocks originally included among the Aravalli series have undergone various modifications and the correlation of the Champaner rocks loosely with the Aravallis, Dharwars, Cuddapahs or with the Delhi quartzites is bound to lead to confusion and therefore an exact definition of the stratigraphic position of the series and its relation with the crystalline complex merit a brief discussion.

In page 8, I have stated that the hornblendic schists and granulites with their associated amphibolites, pyroxene rocks and limestones of the Baria State have their lithological equivalents among the "Aravallis" of Rajputana and of Idar and also among

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[32] A. M. Heron, *Mem. of the Geol. Sur. of India*, Vol. XLV, p. 10.

[33] ..... *General Report, Rec. of the Geol. Sur. of India*, Vol. LXII, Pt. 1, p. 173.

[34] C. S. Middlemiss, *Mem. of the Geol. Sur. of India*, Vol. XLIV, p. 5.

the lower division of the Dharwar schists of Southern India. But here I must point out that the banded ferruginous quartzite, a common associate of larger areas of the hornblendic schists of Mysore, is entirely absent in Baria and therefore I have correlated the crystalline complex of this region with the regions of the Peninsular gneissic complex of Mysore which include generally only bands and bars of the hornblendic schists or their associates and not necessarily all the members of the series together. The hornblendic schists and their associated rocks of Baria are evidently of archæan age.

But none of the clearly recognizable types of the "Champaner series" come into direct contact in Baria with these archæan schists. Between the northernmost band of the hornblendic schist and the mass of the micaceous gneisses of Dhanpur is an intervening zone of foliated biotite granitic gneiss. This granitic gneiss as has been shown is distinctly intrusive towards the hornblendic schists, but whether it is so towards the micaceous gneisses of Dhanpur is not beyond a shadow of doubt. Reasons have already been stated which incline me to view the Dhanpur micaceous gneiss as probably older than and intruded by the biotite granitic gneiss. In their lower zones, the micaceous gneisses also contain blue green hornblende not unlike that of the dark hornblendic rocks.

They show comparatively a lower degree of metamorphism than the hornblendic rocks, and this metamorphism decreases from bottom upwards in the series. The series show lower angles of dip of foliation than the hornblendic schists and are not cut up into ribbons and bands like them. By the general direction of dip, it is surmisable that the micaceous gneisses occupy a higher horizon than the hornblendic rocks, but as they are not in direct contact with the hornblendic schists it is not clear whether they are lying over them conformably or not.

The major portion of the Dhanpur micaceous gneiss may be regarded as metamorphosed series of sediments whereas the hornblendic schists and their associates have already been suggested to be originally igneous.

Due to the occurrence of the same sort of blue green amphibole as that of the archæan hornblendic schists in the lower zones

of these micaceous gneisses doubts would arise whether it has been formed as an independent secondary crystallized product along with garnet and sillimanite, or as a disintegrated product of the underlying hornblendic schists if the micaceous gneiss had been formed unconformably on the eroded edges of the older series, or as an injected or infused mineral from the underlying hornblendic rocks if they were really a series of sills in the lower zones of the micaceous gneiss. Without digressing into a discussion of these points for want of definite evidences, I will only suggest here that the first surmise, *viz.*, the occurrence of the amphibole as a secondary crystallized product is the most probable,—in which case the presence of the mineral in the micaceous gneiss is in no way helpful in finding out the relation between that and the hornblende schist.

Correlation of micaceous gneiss doubtful.

The micaceous gneiss is overlaid by the Baria quartzites which in the Poyelli region are also overlying the phyllitic or slaty schist of the Champaner rocks of the type area, and therefore so far as stratigraphic relations are concerned this gneiss occupies a position similar to that of the Champaner phyllites, but whether it actually represents the same beds of rocks more highly metamorphosed in this region is not clear, as the exposures of the two regions are not continuously traceable. Thus the position of the Dhanpur micaceous gneiss whether it is a component of the upper portion of the archæan schists (Aravallis), or the lowest constituent of the Champaner series is at present doubtful.

Baria quartzites and Rajgad shales similar to Idar quartzites and Phyllites.

The description of the Delhi quartzites and the Phyllite series of the Idar State, not only in their field characters, but even in the general appearance of specimens and their microsections as recorded by Mr. Middlemiss, tally exactly with the characteristics of the rocks I have herein described as the Baria quartzites and the Rajgad shales, with this exception that no large body of the magnesian rocks are found in the Baria quartzite series nor any secondary amphibolic rocks such as those found in Baria are noted among the Delhi quartzites of Idar.

The Delhi quartzites of Idar are the same as the Alwar quartzites of Delhi system of Heron, and the Idar Phyllites

forming a series overlying the quartzites might probably be the equivalents of the Ajabgarhs. Since the Baria quartzites and the Rajgad shales resemble as stated the Delhi quartzites and the Phyllites of Idar, it might be possible to correlate on general lines, the Champaner series with the Delhi system.

Correlation of the Champaner series with the Delhi system.

The Poyelli limestone (Champaners) in its massive unbedded nature, white or dark grey colour, compact granular or saccharoidal texture, the extent of alteration undergone, and in the similar assemblage of secondary minerals developed resemble exactly the Raialo Limestone. Similarly the overlying conglomeratic band, the Poyelli felspathic quartzites and the harsh brittle vitreous Baria quartzites strikingly resemble the Alwar grits and quartzites. The brittle vitreous quartzite is overlaid locally by a thin series of limestone well bedded and jointed, white or dark grey, siliceous type without any secondary minerals. How far this actually corresponds to the Kushalgarh limestone is not clear. Overlying this limestone or in places directly resting on the brittle quartzites are the members of the Rajgad shales which appear to resemble the Ajabgarh slates, shales, etc.

Therefore so far as lithological descriptions and the stratigraphic relations are concerned, the individual series or groups of the Delhi system have their counterparts in the corresponding groups of the Champaner series. How far these apparent similarities might lend colour to the suggestion that the Champaner series of Gujerat are the exact homologues of the Delhi system of Rajputana I cannot say. At the best it is but a dubious procedure to correlate unconnected exposures by mere lithological resemblances, but since among the unfossiliferous formations it is the only criterion which has to be relied on, I suggest that possibility hoping that future detailed surveys of the ground intervening might enable to trace the actual continuity of the two.

Correlation of the Champaners with the Dharwars.

With this probability of the Champaner series being the equivalents of the Delhi system, it might now be examined to what extent the series actually corresponds to the South Indian Dharwars. Relying more on the order of superposition and lithological differences, than on any pronounced evidences of a distinct break,

in Mysore the Dharwars have been classified into a lower and an upper division.[35] I have already stated that the dark hornblendic schists and their associates of Baria resemble, in many respects, the similar types of rocks of the lower division of the Dharwars. Among the rocks of the upper division of the Dharwars there are types like the argillites, phyllites, micaceous and felspathic grits, micaceous schists, sericitic quartz schists, conglomerates, etc., which strikingly resemble the similar types of rocks of the Poyelli group of the Champaner series. In Mysore these types are associated with larger masses of acid igneous intrusives, some of the schistose types being actually traceable into them leading to the inevitable conclusion that the dubious schistose rocks are only the modified phases of igneous members.[36]

In the Champaner series, distinct igneous types are subordinate and all the different groups show indications of sedimentary action leading to the conclusion that the major portion of the series is distinctly clastic in origin. Thus the dissimilarity between the upper division of the Dharwars and the Champaner series rests on a larger preponderance of igneous rocks over sedimentary in the former and quite the opposite in the latter and also in the occurrence of various basic chloritic schists, and greenstones in the former and their absence in the latter.

The harsh brittle, vitreous quartzites of the types so very largely developed in Baria, Idar and Rajputana are not conspicuously characteristic of the Dharwar system of Mysore. No doubt there *are* quartzitic rocks of similar appearance, but they occur mostly as narrow elongated bands seldom covering such wide areal extent as the quartzites of the Delhi system or of the Champaner series. Many of the quartzitic types of the Dharwars are believed to be the altered phases of igneous rocks, either as chilled crushed edges of granites or as altered phases of quartz-porphyries or felsites, or as crushed portions of vein quartz. But apart from such whether there are any outcrops of a really aqueous origin amidst the wide areas of the Dharwars I am unable to say at present.

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[35] W. F. Smeeth, "Outlines of the Geological History of Mysore," *Bull. No. 6*, Dept. of Mines and Geology.

[36] P. Sampat Iyengar, "The Acid Rocks of Mysore," *Bull. No. 9*, Mys. Geol. Dept.

The Champaner series like the Dharwars of Mysore and the Delhi quartzites of Idar have been distinctly intruded by the granites and granitic gneisses of the region, and in the area surveyed I was unable to recognise any granitic mass of mappable dimensions distinctly older than the series. But in Rajputana the lowest members of the Delhi system according to Dr. Heron seem to rest with a pronounced erosive unconformity on the pre-Delhi granites.[37] How far these older granites are different to those found elsewhere intruding the Champaners, the Delhi quartzites of Idar and the Dharwars I am not aware.

Leaving apart this question of the relation of the granites with the series under consideration, I have little hesitation in saying that the Poyelli limestone with its associated schists does resemble in its lithological characters, extent of alteration, and mode of association and occurrence some of the limestones of the upper Dharwars.

If then the dolomitic crystalline limestones of the Poyelli group of the Champaners could be correlated with the Raialo series on the one hand and the limestones of the upper Dharwars on the other, it would naturally follow that the Raialos might be the equivalents of parts of the upper Dharwars. If for a moment this suggested correlation is conceded an interesting issue would arise whether among the upper Dharwars of Mysore are still preserved representatives of the higher groups of the Delhi system like the Alwar quartzites and the Ajabgarh slates, etc. or whether they are absent from the Dharwar area. That is to say whether the upper limits of the Dharwars as recognized in Mysore stops short of the Poyelli group of the Champaner series and the Raialo series of Rajputana or whether it extends upwards having the equivalents of the Baria quartzites and the Rajgad shales of the Champaner series or the Alwar quartzites and the Ajabgarh series of the Delhi system.

It would be unprofitable, no doubt, to speculate on these points and venture on any generalized correlation of the rock groups of the detached areas of these widely separated regions, specially in view of the fact that many of the types of the Dharwars are not regarded in Mysore as of aqueous formation. But

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[37] A. M. Heron, "Geology of N.-E. Rajputana," *Mem. G.S.I.*, Vol. LXV, *op. cit.*, p. 25.

Tabular Statement showing the correlation of the rocks of the Dharwar facies of Baria, Idar, Rajputana and Mysore.

Baria		Idar State	Rajputana		Dharwars of Mysore
Rajgad shales (Micaceous schists, micaceous phyllites, shales, etc.) with intercalated thin bands of quartzites, hornstones, and secondary amphibole rocks	Champaner series	Phyllite series	Ajabgarhs	Champion gneisses	Phyllites, slaty schists, dark grey hallaflinta (of Mr. Jayaram) etc. of Shimoga schist belt (?) (upper Dharwars). All regarded as variants of Champion gneisses.
Thin zone of Dharia siliceous limestone		(?)	Kushalgarh limestone (?)		(?)
Baria quartzites, intercalated with micaceous phyllites and thin bands of secondary amphibole rocks		Delhi quartzite	Alwar quartzites		Quartzites associated with the Champion gneisses(?)
Felspathic quartzites of Poyelli, and conglomerate bed		..	Alwar grits		Felspathic and sericitic grits in association with the Champion gneisses of Shimoga schist belt.
Intrusive quartz porphyry series. .... ?		..	....		Quartz porphyry series of the Champion gneisses.
Poyelli limestone, shale and gritty biotite schists		..	(Raialos ?)		Limestones and mica schists of upper division of Dharwars.
Dhanpur micaceous gneiss .... ?		(?)	(?)		(?)
Hornblende schist, granulites, limestones and diopside rocks intercalated with biotite gneiss		Aravallis	Aravallis		Dark hornblende schists, Tarurites and limestones of the lower division of Dharwars.
Intrusive granites		Intrusive granites	..		Intrusive granites.

still a striking similarity of the lithological characteristics, mode of occurrence and association of the constituent types of these diverse areas induce me to put forward my tentative views of the correlation of these rocks of the Dharwar facies as given in the annexed statement.

Summarizing, the position stands as follows:—The various sub-groups into which the Champaner series have been sub-divided in Baria, correspond both in their lithological characters and their order of superposition to the sub-divisions of the Delhi system as classified by Dr. Heron in 1917. The limestones, shales and sericitic quartz schists of the Poyelli group of the Champaner series consisting of a mixed assemblage of sedimentary and igneous material correspond to the Raialo series of Rajputana, and also to some of the limestones and their associated acidic schists of the Champion gneisses in the regions of the upper Dharwars of Mysore. The zone of conglomerate apparently above the Poyelli limestone might probably correspond to the zone of unconformity between the Raialo series and Alwar quartzites, but in the Poyelli region the "Conglomerate" is neither basal nor undoubtedly sedimentary. Though among the upper Dharwars there are types corresponding to the members of the Baria quartzites and Rajgad shales, it is doubtful how far they can actually be correlated with these, since the types in the Dharwars are believed to be the altered igneous phases and not true sediments.

Therefore all that can be definitely said at present is that the Champaner series, the Delhi system including the Raialo series, and portions of the upper Dharwars of Mysore, especially the schists associated with the Champion gneisses, appear to be the equivalents of one another. The Champaner series cannot be correlated with the Aravalli system or the lower Dharwars of Mysore. There are rocks in the Baria State, like the hornblende schists, diopsidites and limestones, etc., forming the archæan complex which correspond to such. The position of Dhanpur micaceous gneiss, containing garnet, sillimanite, etc., is rather doubtful whether it properly belongs to the archæans or the Champaners. If this scheme of correlation is admitted, either the Delhi system, or at least the Raialo series will have to be regarded as the equivalents of the Dharwars, or among the upper Dharwars of Mysore as classified at present some portions will have to be

removed to constitute a higher zone equivalent of the Delhi system (Purana).

It is interesting to note in this connection that Mr. Sampat Iyengar who examined, in 1920, the Alwar quartzites near Ajmere has suggested them to be the highly quartzose phases of the Champion gneissic granites, intruded and enclosed in the gritty micaceous rock which he thinks to be the same as the Peninsular gneiss of Mysore. He has also given a sketch of an exposure which strikingly supports his views regarding the relationship of the two types.[38]

Struck with the resemblance of the Baria quartzites to those found in association with the Champion gneisses of Mysore, from the very beginning I was also in search of evidences which might prove the Baria quartzites to be of igneous origin and my finding of the opalescent quartz, a very common characteristic constituent of many of the types of the Champion gneisses, in some of the exposures of the Baria quartzites prepossessed me strongly in favour of regarding the quartzites as the actual equivalents of the quartzitic phases of those gneisses and hence probably of igneous origin. This compelled me to examine the junction lines wherever they are exposed with more than ordinary care and though at some points the evidences were suggestive of an apparent intrusive behaviour of the quartzites, yet a closer examination revealed that such was not actually the case, as explained below.

In some of the natural sections near Nawanagar where the quartzites appear bouldery, they show a wavy line of contact with the adjacent interbedded micaceous schist or micaceous phyllite, suggesting an intrusive contact (Text Fig. 4). But at such junction lines there are no effects of contact alteration, and the irregular line of contact may be due to the peculiar conditions of original deposition, such as localized contemporary erosions.

Just at the point where the stream passes E.-N.-E. near the boundary hills of the State north of Nawanagar, the dark grey quartzite inter-bedded with the micaceous phyllite, due to local folding and faulting has been wedged into the phyllite suggesting an intrusive relationship. The occurrence of garnet in the phyllite

P. Sampat Iyengar, "Geol. Observations when on a tour in Central and Northern India", *Rec. of Mys. Geol. Dept.*, Vol. XX, Pt. 2, pp. 78-79.

near the end of the quartzite wedge also tends to corroborate it. But a careful examination of the surrounding ground shows that the quartzite occurs distinctly bedded with the phyllites, and in the exposure, in the faulted zone the quartzite has formed a breccia with the phyllites, showing that both the members have been crushed together, and that the phyllites have developed garnets and knots some distance beyond this zone of disturbance showing thereby that garnet has not been produced as a result of intrusion of the quartzite. The apparent tonguing or wedging of the quartzite band is due to the peculiar mode of faulting.

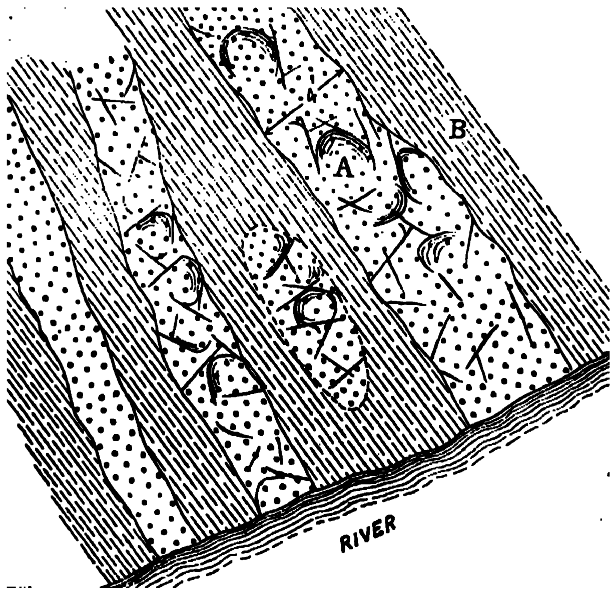

Fig. 4.

A. Dark grey bouldery quartzite. B. Micaceous phyllite.

In the bed of the streamlet joining the Panam to the west of Jhabia in the micaceous rock inter-banded with the quartzite there was a thin vein of quartzite cutting across the schist, looking as if it were a branching vein from the quartzite band. As the exposure is traversed by a number of short veins of quartz, I believe this somewhat quartzite-looking rock is only one of such veins locally crushed. An extraordinarily similar occurrence to that seen by Mr. Sampat Iyengar in the Ajmere area already noted, was found

in an exposure on the northern banks of the Kubutri river. The exact locality of the exposure is at the point marked 543 in the topo, forming the bend of the river to the west of Chundari about 100 yards S.-E. of the temple. Viewed from the southern bank, the exposure looks like a bedded series of the somewhat lighter coloured quartzite and the darker gritty micaceous schist folded into a gentle local syncline (Text Fig. 5). From a distance owing to the general grey or dark grey colour of both the types it is not possible to see the exact bounding lines of the two rocks.

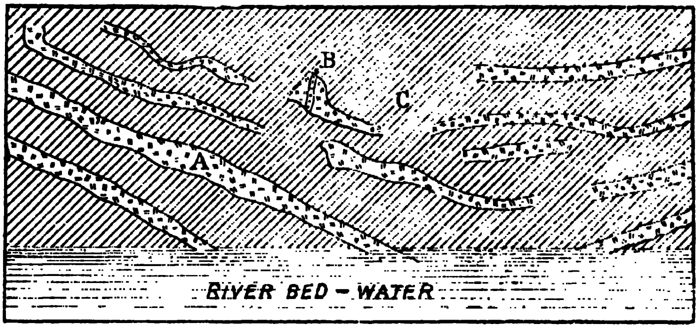

Fig. 5.

A. Brittle quartzite. B. Quartz vein.
C. Micaceous schist.

When bits of this are closely examined, the quartzite runs are found to be disposed as a number of elongated lenticular bands, sometimes with bulged ends and at others like sheared lenses. Here and there the continuations of the disconnected ends of the lenses may be traced slightly displaced with a lateral shift, and the separated ends show also some drag. Very generally the transverse quartz veins are confined only to the quartzites, and do not proceed into the gritty micaceous schist. They are generally single, rarely branching, usually 2 to 4 inches wide though some are found to be as wide as 6 inches, while others occur as thin stringers closely welded with the quartzite and scarcely perceptible (Text Fig. 6). The N.-E. running veins, that is, those roughly parallel to the general strike of the rocks, are larger and also cut across or transgress the strike of foliation of the gritty schists. There are no pegmatites, aplites or any granitic textured veins in the complex, and but for the occurrence of these

apparent xenoliths of quartzites there were no other foreign or cognate inclusions. The exposure shows also patches of slickensided bluish grey gritty phyllitic schist.

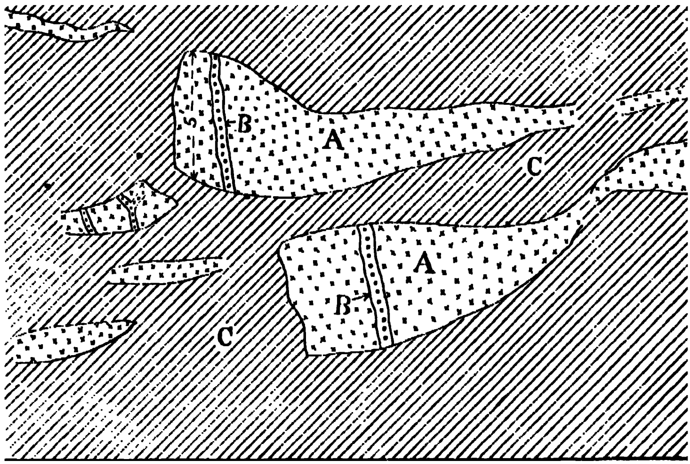

Fig. 6.

A. Brittle quartzite. B. Quartz vein.
C. Micaceous schist.

It is difficult to explain this structure by ordinary process of faulting of a series of sedimentary beds. But if the gritty biotite schist were actually the crushed finer edge of a granitic rock as surmised by Mr. Sampat Iyengar, then the occurrence of the quartzite as cut out strips in the invading rock could be easily understood. This zone is not far from the edge of the granitic gneisses and it is only at such places that these rare instances have been found. It is quite possible, that mixed up with the phyllitic micaceous schists are also tongues and bands of the crushed phases of the intrusive biotite granitic gneisses as found in the Devgad valley exposures. But these are only the additional proofs of the quartzites being older than the granites. But clear evidences showing the intrusive nature of the *quartzites* were nowhere found. In the main mass, and especially towards the top of the series are evidences such as sun-cracks, ripple marks, etc., in addition to the distinct signs of bedding, indicating a shallow water facies of deposition to a major portion of the Baria

quartzites. The presence of opalescent quartz characteristic of the Champion gneisses (igneous) in these quartzites perhaps requires an explanation. This is noticed as minute dots of dark grey or greyish blue in the outcrops not far from the edges of the Deccan Trap. I attribute this opalescent nature of some of the quartz grains to a change in the physical characteristics which they undergo when re-crystallizing under changed conditions of temperature and pressure. In the Jhabu plateau, similar blebs of opalescent quartz are also found in the siliceous limestone near the edges of the Deccan Trap. It is unnecessary to digress into a discussion here regarding the mode of origin of this opalescent quartz. It would serve the purpose if I mention that it need not necessarily be an inherent characteristic of any particular type of igneous rock.

Therefore so far as the Baria quartzites are concerned there are no strong evidences to regard them as orginally igneous, and all the available evidences though considerably defaced still point to an indication of their being originally sediments.

The improbability of the rest of the types of the area, *viz.*, the phyllites, shales, etc., being primarily of igneous origin, need not be again dilated or discussed here.

CHAPTER VI.

Igneous Intrusives.

Depending largely on their mineral composition, similarity of appearance and field behaviour which form at present the only bases for correlating widely separated exposures of igneous masses, I have tentatively classified the granitic rocks of the Baria State as divisible into 3 groups of probably different epochs of intrusion. For purposes of this note I will describe them by the adoption of local names as under :—

(1) The Chelavad granites.
(2) The Sagtala granites and granitic gneisses.
(3) The Haveli granites.

All these show a distinct intrusive relationship with the Rajgad shales and the Baria quartzites and consequently must be of post-Champaner period. I have not found in the area any granite distinctly older than the Champaner series.

Among these various granites, the Haveli granites are distinctly intrusive into the Sagtala granites, but their exact relationship with the Chelavad granites is not clear. Similarly the relation between the Chelavad granite and the Sagtala granite is also not clear as they do not come into contact with each other. But relying on certain characteristics which have been found to be peculiar to such series as studied among the different granitic intrusives in the Dharwars of Mysore, I have presumed the Chelavad granite to be older than the Sagtala granite. The three divisions of the granitic series of this area, *viz.*, the Chelavad granites, the Sagtala granites and the Haveli granites, correspond in appearance, lithological characteristics and their field relations to the Champion gneissic granites, Peninsular gneisses and the Closepet granites, of Mysore, respectively.

The Chelavad Granites.

General character and distribution.

The exposures of this group occur like a pear-shaped mass in the S.-W. portion of the Rajgad mahal conspicuously outcropping in the vicinity of Chelavad and Ranjitnagar. The outcrops consist of low hills of single huge tors or clusters of piled-up boulders rising

to a height of scarcely more than 150—200 feet above the level of the plain which also shows obscure outcrops of the same disintegrated granite. For the most part the rock is dull grey, greasy-looking and porphyritic showing large crystals of grey felspar of about 1 to 1½ inches long. The rock is medium to coarse textured and in addition to felspar, shows fairly coarse grains of slightly bluish or bluish white quartz and coarse plates of black mica. Aplites, pegmatites and other vein material is strikingly absent, but the outcrops show promiscuously an abundance of xenolithic inclusions mostly oval, but also of varying shapes and sizes. These are finer textured, dark grey, gritty and micaceous and are studded with blebs of blue opalescent quartz and small crystals of platey felspar (B/82). These xenoliths have a striking resemblance to the micro-granites of the Champion gneissic series of Mysore. They have a sharp contact with the granite and in most instances are easily separable and having fallen out in the ordinary process of weathering have left cavities of their original shapes. Besides these there are also numerous inclusions of micaceous gritty schists which are evidently the incorporated and altered material of the pre-existing sediments.

Relation with other series of rocks.

This granitic series is distinctly intrusive into the Rajgad shales and possibly also into the rocks of the Poyelli group. At its northern edge about 3 furlongs S.-W. of Δ 469 this granite, veins into the Rajgad shales and has converted the band at its contact into a micaceous schist. Again at its eastern edge where it abuts against the Rajgad shales on the eastern flanks of Δ 601, the granite shows evidences of intrusion and contact alteration. The micaceous phyllite close to the granitic contact has become very dark, tough, brittle and bouldery losing all its original signs of bedding and lamination. In fact the outcrops of this rock stand like a line of dark boulders. In places the rock has developed garnets passing into a garnetiferous micaceous granulite. The granite itself has become dark grey, medium grained and abnormally micaceous. This type has small porphyritic felspars of ¼ inch long and shows a striking resemblance to the xenoliths found in the porphyritic granite further west near Chelavad, but so far as noticed it has not got the opalescent blue quartz. There are also still darker small basic patches which are doubtful if they

are really the incorporated and modified xenoliths or actual basic segregations. In this region the granite is veined by a few aplites and pegmatites containing tourmaline in streaks and patches. On the S.-W. flanks of the same hill Δ 601, the granite passes into a type of coarse interaction diorite. Without digressing into a detailed discussion as to how far actually either differentiation or assimilation can bring about such variations in an igneous mass, I have to state simply here that the dioritic rock is the result of assimilation of the shaly material by the granite and subsequent recrystallization, since in this region are still noticeable a few lenses of altered granulitized micaceous phyllite which seem to have escaped disintegration and complete assimilation. That such assimilation can go on to a certain extent is proved by the experiments of Stansfield (*Assimilation and Petrogenesis* by J. Stansfield, Part 1, Chap. III).

Contact alterations and assimilation.

To the south of Kalsar beyond the influence of the granitic zone the shales are again normal.

The following micro-slides of the different types illustrate the nature of the alterations produced:—

B/104. Compact dark grey micaceous granulite showing in section a granular aggregate of quartz, red-brown biotite and also some colourless mica.

B/105. Very similar to the above, but has developed in addition garnets and a few crystals of pyrites.

Altered types.

B/107. Dark grey micaceous granitic rock showing platey felspars seen more or less as infused crystals. The slide shows the abnormal character of the rock. It contains quartz, microcline and other felspars crowded with sillimanite, brownish yellow biotite, a few crystals of hornblende and sphene.

B/108. The interaction type. A coarse speckled rock showing hornblende and felspar. The slide shows large patches of blue-green hornblende altering in places into biotite and coarser

crystals of plagioclase mostly sericitized. Biotite as primary mineral and quartz are absent.

To the south the contacts of this granite with the Champaners are not noticeable as the ground consists of thick soil and forest growth. But still I regard the dark porphyry rocks occurring in the Poyelli group referred to in page 31, as differentiated satellitic dykes of this granitic mass.

At the south-western edge the granite passes into a compact sericitic quartzite near its contact with the schists, the altered phases of which are seen here as a type of sillimanitic gritty schist.

It is thus clear that this pear-shaped outcrop of granite has at its junction altered the schist members diversely at various points and has also got itself changed to a certain extent along some points of its contact. The eastern altered phase of the micaceous gritty schist and the opalescent quartz-bearing micaceous granulitic xenoliths bear a striking resemblance to the micro-granitic phases and their altered forms the gritty micaceous gneisses of the Champion gneissic series of Mysore. Like that gneissic series, the granite of the Chelavad area has got a zone of interaction diorite. While the marginal altered types and those occurring as xenoliths show their resemblances to the members of Champion gneisses, the normal granite itself both in the field and in specimens is not far different in appearance to the Haveli porphyritic granites. This will naturally create a doubt whether in this area there was primarily a fine grained biotite granite which was the first to intrude the schist members inducing contact alterations in them and getting itself also altered by becoming more basic by marginal assimilation has been subsequently intruded and incorporated as xenoliths by the later series of coarse porphyritic granites (Haveli granites), or the finer and more basic phases are only the contact chilled and basified portions of an older porphyritic granite itself unconnected with the Haveli granite series. On this point the evidences are not clear as these two porphyritic granites of the Haveli and Chelavad areas do not come into contact with each other. There are no perceptible differences in the mineral constituents and appearance between these two porphyritic granites. Such of the differences in outward appearances as are noticeable I will state later.

Sagtala Granites.

Distribution. The complex series of granites and granitic gneisses which have been comprehensively styled as Sagtala granites form as different continuous chains, all the high hills in the southern portion of the Sagtala mahal, the Sewania hills and also a large portion of the Rattanmahal hill ranges. Eastwards they pass into the zone of the archæan crystalline complex, the gneissic types of which I consider as the modified phases of these granites. To the north also they are bounded and pass into the crystalline complex. To the west they are lost in the complex pegmatitic zone of the Haveli porphyritic granite series, intruded and cut out by them, only remnants occurring here and there scarcely recognizable as types of a series distinct to that of the porphyritic granites. These are noticeable chiefly along the southern flanks of the hill masses marked in the topo sheets as 758, 772 and 753.

Variations. Variations of types amongst the granites of this series depend mostly upon the relative proportions and mode of disposition of the dark minerals like biotite. These variations are more pronounced at the borders of the granitic series where the types get distinctly foliated, banded and gneissic. Bands of porphyritic types are noticeable here and there as in the hill groups to the north of Devia and in the valley to the east of △ 1370 chain of hills, but in such types the porphyritic felspars are scarcely larger, than $\frac{1}{4}$ to $\frac{1}{2}$ an inch long unlike the porphyritic felspars of the Haveli granite series. The main masses are free from pegmatites, aplites, quartz veins and also from incorporated xenoliths. But still such are not entirely absent.

Aplites and pegmatites rare. To the S.-E. of △ 1370 hills, proceeding south from the band of porphyritic granite are found thin aplitic veins 3 to 4 inches wide, consisting of quartz and pink felspar cutting across the granite in a N.-N.-W. or N.-N.-E. direction. Further S.-E. nearing the State boundary, pink pegmatite veins become more conspicuous, but all these are generally free from tourmaline and muscovite.

Inclusions are scarce, but still in the village site of Sagtala, and at the edges of the granitic zone about a mile due south of

Devi and east of Bediphaliya are found lenticular inclusions and bands of dark grey quartzites. Occasionally inclusions of scattered loose boulders of a very dark green amphibolite of coarse to fine texture have also been noticed. In fact an increase in the number of such inclusions is always accompanied by the banded and gneissic types of the surrounding granites. Among the Sewania hill exposures, are found here and there patches of banded grey biotite granitic gneisses as irregular inclusions amidst the more homogeneous normal granite. Though on the whole the granitic portions appear to be somewhat later than the gneissic phases, still the field evidences are suggestive of their being of the same period of eruption; those which intruded earlier into the pre-existing schists getting banded and foliated leaving the residual portions to crystallise as homogeneous masses.

Inclusions.

Generally the Sagtala granite is an even grained homogeneous fine to medium textured normal type, light grey in colour. But due to the presence of pink crystals of felspar in many of the exposures the granite gets distinctly pink. The gneissic phases also correspond to these being either pink or grey granitic gneisses. There is no perceptible difference among the mineral constituents of the granitic and gneissic types.

General character.

A study of the microslides of specimens of these different types shows, that the granites contain normally irregular grains of quartz some showing undulose extinctions as in B/152 either free or having hair-like inclusions as in B/105, untwinned felspar and also multiple twinned plagioclase mostly kaolinized (B/152, B/155), biotite either brownish and partly chloritized in some, or honey yellow and greenish in others (B/132). Chlorite and epidote occur as secondary minerals in many of the specimens. Apatite is found as a common accessory, while magnetite has been conspicuously noticed in the outcrop to the south of Lakhna. The more basic forms show a larger proportion of biotite, sometimes hornblende and a few crystals of sphene.

Micro-characters.

The foliated types show evidences of having both primary and secondary gneissic bandings. Bounding the southern side of the sillimanite quartzite of the Δ 1475 hill range is an exposure of

the granitic gneiss which shows different stages of crushing forming types of augen gneiss (B/205), mylonitized gneiss and banded granitic gneisses, the bands consisting of sheared streaks of biotite and lenticles of salic minerals, where evidently the banding has been produced as a result of crushing. But in the majority of exposures the gneissic banding is primary, due to movement of magma while consolidating as seen further southwards and S.-E. all along the section of the Bhanpur ghat.

Gneissic banding.

Unlike the Chelavad granites, both the granites and granitic gneisses, especially the latter have their inclusions most often in the form of elongated bands and lenses. Hornblendic granites and quartz diorite types are found as local modifications in association with included bands of the hornblendic schists, but types of the interaction diorite as a result of assimilation of larger blocks of extraneous basic material as noticed in the Chelavad granite area are rather rare here. Unlike the Chelavad granites again, which form more or less a series of uniform granites varying only in texture, the granites of Sagtala form a heterogeneous complex, showing different phases of consolidation. This is well illustrated by a small outcrop seen to the S.-E. of Khanpur where a rectangular patch of $4'' \times 2\frac{1}{2}''$ of dark grey granite with 2 aplite veins of different periods of crystallization has been enclosed by a mass of light grey granite (Text Fig. 7).

The Sagtala granites are in contact on all sides excepting at their south-west border, with crystalline schists and as such whatever alterations they might have induced in the invaded schists are difficult to detect. The production of pale green pyroxene, epidote and garnets in the hornblendic schists forming bands in the granitic gneisses, and also the formation of limestones have already been suggested while describing them under archæan crystalline schists as due to contact alterations effected by this granitic gneiss or its finer grained aplitic veins. Apart from these the production of sillimanite in the gritty micaceous quartzites of the Δ 1475 hills and of garnets and sillimanite, etc., in the micaceous gneiss in the southern slopes of the Δ 1745 hills have also to be attributed as due to the contact action of these granites.

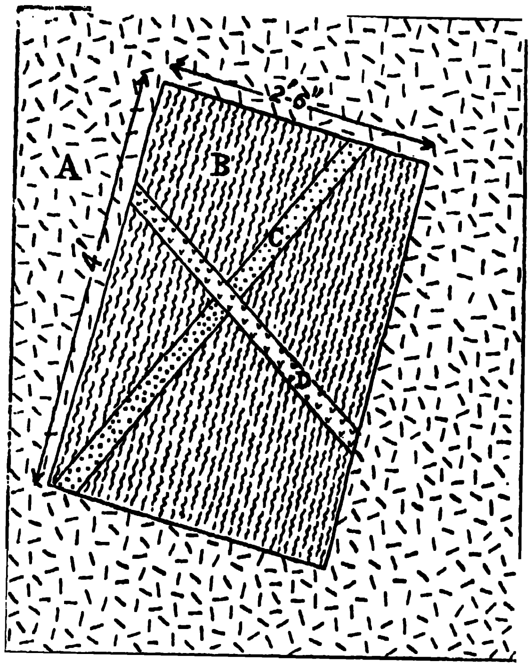

Fig. 7.

A. Light grey granite.
B. Dark grey granite.
C. Older aplite.
D. Younger aplite.

Intrusive relations.

On their western side, the Sagtala granites abut against the series of Rajgad shales, and along the zone of contact a number of bands and patches of a highly weathered micaceous phyllite (of the Rajgad shales) are found as inclusions in the pegmatite gneiss. Between Rampur and Devi in the contact zone was found a thin quartz vein containing long blades of pinkish andalucite (B/138), and a few blades of pearly sillimanite. On this side, bordering the edge of the granite is a persistent thin band of dark grey quartzite, in outward appearance not dissimilar to the quartzite bands of the Rajgad shales, but appearing like a finer grained crushed granitic phase in the slide. The slightly coarser veins of normal granite are found welded with this type which seems to have resulted as a crushed chilled edge of the granite.

An offshoot of this granite projects westwards and loses itself amidst the complex constituting the various components of the zone of Haveli pegmatites. Signs of this gneissic granite are

still perceivable here on the southern flanks of the $\Delta 758$ and $\Delta 772$ hills near Khanpur where they form complex exposures of lighter and darker grey granitic gneisses, basic patches, aplitic veins, etc.

Many of the characteristics of the Sagtala granites, such as the gradation of the series into granites and granitic gneisses, the nature of the associated inclusions of the crystalline schists and the types of alterations effected in them and the general appearance of the various types as seen in the field all remind me of the characteristics of the granitic series described as "Peninsular Gneisses" in Mysore.[39]

Haveli Granites.

Distribution. The rocks of this series are largely exposed in the western portion of the Haveli mahal and form the chains or clusters of bouldery hills of the Singor, Khanpala, Damavav and Katu regions (Kanta of topo). They form sometimes dense clusters of bouldery or conical hills dotted with teak forests through which in the cold season it is difficult to move about freely due to an exuberant undergrowth of matted shrubs.

General characters. The granitic rocks of this series are generally coarse grained and almost always porphyritic, varying in colour from pink to grey according to the colour of the dominating felspars. The pink type is in excess of the grey. One conspicuous band runs north-west from near Bamroli to Richvani. Other patches are found to the west of Ankli, near Katu (Kanta of topo), and elsewhere mixed up with the grey. The felspar crystals are usually very coarse sometimes being 2 to 3 inches long either equant, tabular or prismatic. Primary gneissic banding is observable at some places as in the exposure on the eastern bank of the streamlet east of Chatha where the pink porphyritic granite shows a rude flow structure, the coarse porphyritic felspars being arranged in undulating definite rows. Here the granite has been traversed by aplitic veins which themselves have been sheared and faulted by movement. Though generally the porphyritic felspars lie in the direction of flow, rare instances were also noticed where their longer dimensions were athwart to the general direction of foliation suggesting that the porphyritic crystals had a free rotary movement

[39] W. F. Smeeth, "Outlines of the Geol. History of Mysore", *op. cit.*, p. 17.

in the consolidating mobile magma. The grey porphyritic types occur very often as marginal phases and grade into the non-porphyritic coarse textured homogeneous granites.

Associated with these granites are found at some places as near Chatha, about a mile N.-E. of Khanpala, near Kakalpur and elsewhere small dyke-like runs of finer grained granite and syenitic rocks which behave like later differentiated members in the series. Aplites and pegmatites are very common, especially so towards the south where the series intrudes the Rajgad shales.

Well developed sets of master joints are seen in many of the outcrops, but mural jointings giving the rock a pseudo-bedded appearance is noticeable prominently only on the western banks of Ujol river about ½ a mile to the N.-N.-E. of Kakalpur police station (Plate 9, Fig. 2). Differential weathering and erosion along such joints have produced benches or galleries (Plate 11, Fig. 1), and as a rare instance a small natural arch. Due to the scouring out and removal of inclusions of softer rocks with which this series also abounds, cup-shaped cavities, larger cauldron-like hollows and irregular caves (Plate 10, Figs. 1 and 2), have often been produced in the masses. Like the Chelavad granites these also consist of massive boulders, but they build up clusters of high hills, 400–600 feet above the level of the plains.

Evidences of intrusion.

The granites of this series have been found to intrude on their northern side the Baria quartzites, on the south the Rajgad shales, and on the south-east the Sagtala granites.

The hill ridge of Δ 663, about a couple of miles N.-N.-E. of Rajgad consisting of the dark grey brittle bouldery quartzite of the Baria quartzite type has been forked by a tongue of this granite, proceeding from the main mass from the N.-W. Further evidences, proving that these granites are intrusive into the Baria quartzites have already been noted (*vide* page 55) while describing the latter series of Rocks.

Intrusion into Rajgad shales.

Eastwards of this ridge, the granite all along its southern margin sends out branches veining the phyllitic schists for lengths of 8-10 feet and every now and then the main mass itself or its pegmatoidal phases cut across the strike of phyllites breaking them up into larger and smaller blocks of inclusions (Text Fig. 8).

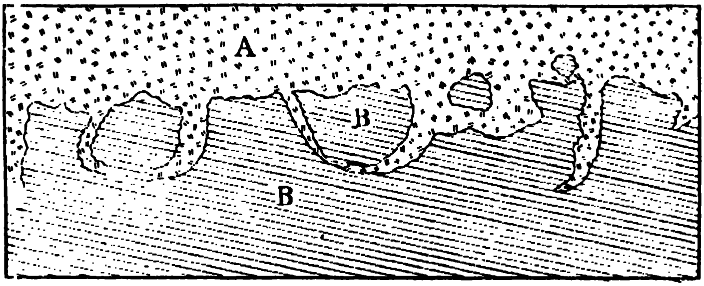

Fig. 8.

A. Haveli granite. B. Rajgad shales.

The smaller torn and enclosed blocks of about 3-4 feet in diameter have often been warped or crumpled up looking like fine grained mica schists, but the larger bodies are still, more of the nature of micaceous phyllites than mica schists though both types are present.

This zone of contact alteration is fairly wide extending from the edge of the granite for at least 5 to 6 furlongs. Near the southern edge of this granitic series, mixed up with numerous pegmatites are found inclusions of highly weathered biotite gneisses. Amongst these are the extremely altered phases of the Rajgad shales which have become micaceous gneisses developing garnet and sillimanite and possibly kyanite, without any andalucite, cordierite or staurolite. The highly crushed, weathered and gneissic phases of the Sagtala granite series mixed up in the zone can rarely be recognized and differentiated from the metamorphosed Rajgad shales, but the former as a rule contain more of quartz, less of biotite and no sillimanite.

Exo-thermic alterations in Rajgad shales.

The Rajgad shales far from this line of contact are phyllitic and have developed rounded knots, which consist of either indurated granular quartz coated with filmy mica, or of overlapping minute scales of biotite, as in B/72. The exposures of such knotted types are promiscuous in the village site of Palla.

Endo-thermic alterations.

The edge of the granite itself by pneumatolytic and hydatogenetic alterations has been converted in places into a garnetiferous, sericitic, tourmaline quartz schist showing still a few crystals of felspar, (B/69 and B/70).

While the evidences pointing out the intrusive relationship of this granitic series with the Baria quartzites and the Rajgad shales are so very clear and definite where the intruding and intruded series of rocks are of dissimilar character, similar evidences leading to the suggestion that they are also intrusive into the Sagtala granites cannot be expected to be so very definite or positive owing to their both being igneous intrusives of similar composition and character.

Evidences of intrusion into Sagtala granites.

Among the various inclusions of the gritty micaceous gneisses in the complex zone of pegmatites some are no doubt the crushed representatives of the eastern biotite granites of the Sagtala area. Apart from such doubtful instances, in the main mass of this granitic series, are often found inclusions of grey biotite granitic gneisses of the type of Sagtala granites, penetrated by aplitic veins proceeding from the porphyritic granite as seen in the sketch taken at spot from an exposure immediately south of the nulla 3 to 4 furlongs south of Kanta (Text Fig. 9).

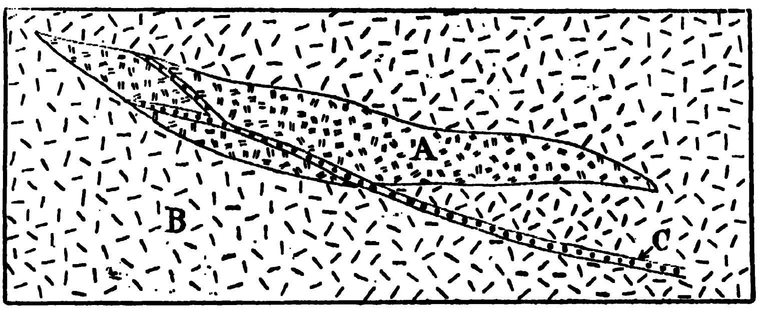

Fig. 9.

A. Biotite granitic gneiss. B. Coarse porphyritic granite.
C. Aplitic vein from the porphyritic granite.

Another good instance of such was noticed on the western bank of the Ujol river, about 50 yards south of its confluence with a branch nulla, or about 100 yards S.-S.-E. of Kakalpur police thana where the highly foliated biotite gneiss with its twisted and faulted aplitic veins has been cut out and tongued into by the grey granite of the Haveli granite series (Text Fig. 10).

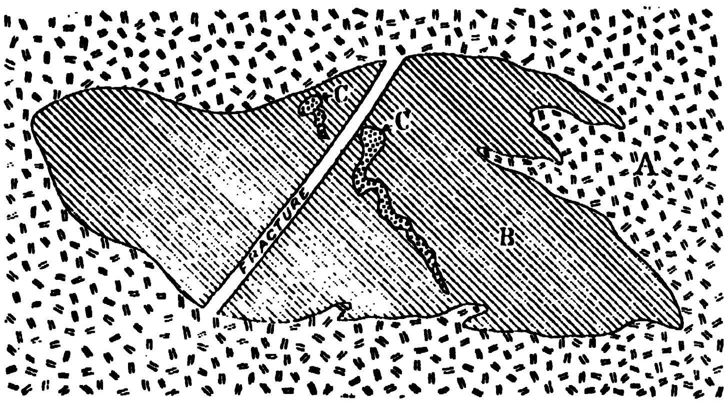

Fig. 10.

A. Grey Haveli granite. **B. Biotite granitic gneiss.**
C. Aplitic vein in the gneiss.

Around the margins of the small stock of granite of this series forming the Δ 1234 range of hills, the foliated biotite granitic gneiss dips away in all directions as if it has been thrust out by the protrusion of the granite stock.

To the west of Bor, a thin capping of the disintegrated biotite granitic gneiss of probably the Sagtala granite series is found resting on the pink porphyritic granite as a scum or layer of about 1 to 2 inches thick.

Amidst the Sagtala granites extending E.-S.-E. from near Tokarwa to about 6 miles is an outcrop of the Haveli granite behaving like a sill.

In addition to these evidences there are numerous veins and pegmatites cutting the Sagtala granites along the line of junctions.

What the relation of this granitic series might be to the Chelavad granites is not clear since the two series are not contiguous to each other. Similar to that series this is also porphyritic, has numerous inclusions, has tourmaline as a very promiscuous vein mineral, but differs from that series of granites in very many respects as noted below:—

Comparison between the Chelavad Granites and the Haveli Granites.

Chelavad Granites.	Haveli Granites.
1. Their lines of contact with the Champaners and Rajgad shales are in broad indented curves following the edges of those series.	Their lines of contact with the Rajgad shales are jagged, the granites breaking across them as apophyses.
2. Inclusions in the mass are numerous and many of them contain opalescent quartz.	Inclusions are common, and are of the type of gritty mica schists and none show the opalescent quartz.
3. Pegmatites and aplites though noticeable are rather rare.	Pegmatites and aplites are very conspicuous specially along their border.
4. Dyke phases in the granitic regions are not noticeable, but such as are found among the invaded older series are presumed to be the differentiated phases of these granites.	Dyke phases occur as apophyses from the main mass and also as later differentiated phases cutting through the granites themselves.
5. Evidences of assimilation with the formation of dioritic types noticed.	Assimilation not characteristic.
6. Contact alterations :— *Exogenic* :—Silicification and production of mica converting the shales into a micaceous granulite. *Endogenic* :—Slight contact basification.	*Exogenic* :— Production of mica schists, knotted schists, etc. *Endogenic* :—Pneumatolytic and hydatogenetic alterations with the production of garnet, tourmaline, etc.
7. Phenocrysts of felspar though coarse, seldom exceed 1 to 1¼ inches. Grey and greasy.	Porphyritic felspars often very large, pink as well as grey,—pearly.
8. Quartz, semi-opaline blue or grey, somewhat rounded.	Quartz irregular, white and greasy.

	CHELAVAD GRANITES.	HAVELI GRANITES.
9.	Biotite occurs in small roundish plates.	Biotite as black streaks or flakes or irregular plates.
10.	Tourmaline though present is rather rare and occurs as small crystals.	Tourmaline very conspicuous along with muscovite in the pegmatites.

These points of differences may not be of any special importance for genetic considerations, but as the two masses do not come into contact with each other I have noted them as accessory aids for purposes of correlation.

The Haveli granites have many points of resemblance in their field relations and appearance to the Closepet granites of Mysore and I have already noted that the Chelavad granites show some characteristics of the Champion gneisses of that State which are held to be distinctly older than the porphyritic granites of the Closepet granitic series. If the correlation of granitic exposures of widely separated areas by such evidences as those detailed is justified, then on the analogy of the field relations of the different granitic series of Mysore, the Haveli porphyritic granites may be regarded as subsequent in age to the somewhat similar types and others of the Chelavad area.

The Haveli porphyritic granite also resembles to a certain extent the Idar granite, but whether in that area there are any others of different series corresponding to those described here is not evident.

TYPICAL EXPOSURES.

Bordering on the west the Baria quartzites, exposures of this granite become conspicuous as isolated hillocks or groups of hillocks about 3½ miles to the south and west of Devgad Baria. The granite just near its contact with the quartzite series is seen immediately south of Buval as a number of highly weathered, crushed lenticular sills of a coarse biotite granitic gneiss. But the definitely recognizable typical exposures of this granitic series are noticeable here forming the Δ 987 hills. This hill group consists of a good exposure of bouldery biotite granite, medium grained, light grey and foliated in places. Felspars occur in them as long laths, white and pearly and they get gradually coarser to

the south until near Singor they become very coarse. Here the porphyritic felspars are white and are probably oligoclase, but there are also small phenocrysts of bluish labradorite. The white porphyritic felspars are coarsely prismatic, tabular or in coarse equant forms, of the dimensions of 1¼ to 2½ inches square.

A wide band of outcrops forming the hill groups in the vicinity of Khanpala, the Δ 1036 hill group, the outcrops S.-S.-W. of Singor and to the S.-S.-E. of Δ 1107, have their porphyritic felspars of different shades of pink, but eastwards near Bamroli and further they are again often white. To the S.-S.-E. of Δ 1107 the granite is distinctly foliated with a definite strike of N.-W. and S.-E. similar to that of the quartzite series. Though on the whole the granite is a medium to coarse textured porphyritic type, there are portions in the mass which are uniform and fine grained and in some places also gneissic. Inclusions of fine micaceous grits of different shapes and sizes are noticeable in the exposures about 100 yards N.-N.-W. of one of the hamlets of the Singor village.

Kanta outcrops.

The hill ranges to the south of Kanta (Katu) show conspicuously the porphyritic types. Near the head of the nulla which flows northwards to the west of Kapdi is found an exposure of biotite granite highly foliated and gneissic, the strike of foliation being E.-N.-E. Porphyritic felspars are still observable in this. The exposure here shows a number of inclusions of dark grey garnetiferous micaceous granulites (B/23), and finer grained gritty micaceous gneisses, torn and incorporated resulting in the movement and banding of the magma. Immediately south of this spot the porphyritic type is well exposed, highly jointed, the master joints running E.-S.-E.

Damavav outcrops.

In the vicinity of Damavav are seen a number of exposures of this granitic series. To the north of Damavav are found coarse textured non-porphyritic grey granites where the biotite is seen as groups or bunches of coarse crystals. The exposures about 3–4 furlongs N.-N.-W. of Damavav are veined by light grey finer grained aplitic types varying in width from about 3 inches to 2 or 3 feet. The exposures as usual are well jointed, the direction of joints being E.-S.-E. To the south of Damavav the types are coarsely porphyritic, either pink or grey, and they are seen

amidst the teak jungles all along southwards for a distance of 7 to 8 miles.

For petrographic descriptions the Haveli granites may be sub-divided into a number of types depending upon the mineral constituents and texture but since a lengthy description of all such minor variations is likely to swell the volume of this report, it is sufficient if such variations are merely noted, as below:—

Coarse porphyritic grey granite—B/56, B/57.
Coarse porphyritic pink granite—B/30.
Coarse textured homogeneous non-porphyritic grey biotite granite.

Finer textured normal grey granite. Finer textured pinkish granite. Gneissic granite.	Occurring as apophyses intruding the Rajgad shales.

The characteristics of the constituents as seen by an examination of a number of micro-slides from different outcrops are:

Quartz, granular to hypidiomorphic often full of liquid inclusions, some having rod-like inclusions of apatite (B/33).

Felspars, are generally orthoclase, albite and oligoclase and rarely microcline. Very often they are coarsely prismatic, mostly altered to kaolin, rarely to sericite. The partially altered and unaltered forms show albite twin striæ.

Micas, the biotite is of a honey yellow colour, occurs as coarse plates and flakes and shows considerable absorption. Muscovite is rather rare, (B/24).

Accessories, apatite, chlorite, tourmaline and allanite have been noticed, the latter two being generally found confined to finer grained dyke-like members.

DIFFERENTIATED HYPABYSSAL ROCKS.

Aplites.

Acidic dykes and later differentiates:—In the main mass of this granitic complex are found round about Kakalpur, Chatha and Richvani thin bands of finer grained pinkish or pale pinkish acidic rocks traversing like contemporaneous veins or outcropping like a line of boulders. The contacts between the bouldery outcrops and the normal granites are almost always

concealed by soil and disintegration products. But still, the fact that these finer grained acidic members are distinctly later differentiated products of the series is clearly made out from a small exposure about 5 to 6 furlongs east of Damavav, on the northern side of the cart track about a hundred yards east of the spot where it crosses the big north and south flowing stream. Here the fine grained greyish granulitic granite clearly encloses a patch (2½′ × 1′) of the pink porphyritic granite (Text Fig. 11). About 3 to 4 miles S.-W. of Damavav, 3 furlongs east of the

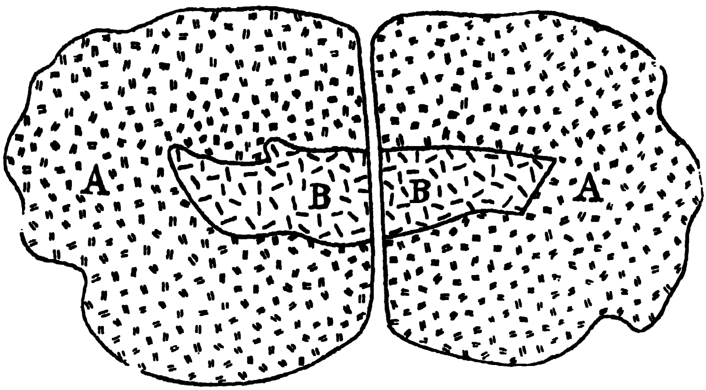

Fig. 11.

A. Fine grained granite. B. Coarse porphyritic granite.

point ⊙ 630 is again seen a dyke-like run of similar type enclosing irregular small patches of the coarse porphyritic granite. The contact between the two is quite sharp at some points while at others it is welded.

These dyke-like members vary somewhat in their mineral constituents and are divisible into Syenitic aplites, Granitic aplites, Tourmaline aplites and Allanite aplites. Most of these are characterised by a granular texture having platey crystals of kaolinised felspars, orthoclase and oligoclase, rounded grains of quartz when present, and biotite, tourmaline, allanite, etc., as accessories.

Altogether about 10 of these were noticed, and some are noted below:—

Syenitic aplite :—In a north and south branch nulla joining the N.-E. flowing main one between Lavaria and Vau, near the footpath from Kakalpur to Kanta, at a point about ½ a mile north of ⊙ 698 is a small run of bouldery pink acidic rock outcropping for about 50 to 60 feet with a width of 3–4 feet. The rock is a fine grained, pink crystalline type showing small plates of deep pink felspar, and dots of oily green or black femic minerals. Its section (B/19) shows fairly coarse prisms of felspar charged with pinkish alteration products showing in clearer areas narrow laminæ of albite twins. The extinction angles as measured indicate it to be oligoclase-andesine. In addition there are also coarser allotrimorphic grains of untwinned orthoclase. Emerald green chlorite slightly pleochroic occurs as a secondary product altered from hornblende. Reddish brown sphenic altering ilmenite and a few scales of muscovite are found as accessories.

Tourmaline aplite :—About a mile further S.-W. in the vicinity of Nava a pinkish aplitic vein dotted rather sparsely with the dark minerals is found traversing the granite. This in section (B/21) shows an equal proportion of allotrimorphic granular untwinned orthoclase, acid plagioclase, quartz and purplish brown tourmaline.

Biotite aplite :—About ½ a mile N.-E. of Vau running in an E.-N.-E. to N.-E. direction is a band of bouldery weathering pale pink aplitic rock showing in addition to minute plates of pearly felspar, black and dark reddish dots of femic minerals. Its slide (B/31) shows like the rest highly weathered platey or prismatic crystals of felspar and fairly coarse grains of quartz and a few ragged flakes of green chlorite or chloritising biotite. There are also scales of sericite and biotite.

Syenitic rock :—In the stream section between Tokarwa and Goja amidst the lenticular sill of probably the Haveli granite series is an exposure of a band, of a handsome dark pink to flesh coloured syenitic type of these dyke members. Its microsection (B/158) shows mostly felspar crystals consisting of simple twinned orthoclase, oligoclase and also andesine, bluish green chlorite derived from hornblende, very few grains of quartz and as accessories sphene, epidote and magnetite.

In some of these types which have been sheared owing to their forcing themselves amongst narrow channels of access, the

felspars have developed long fusiform or spindle shaped lacunæ which are either straight and parallel or bent along their course (B/34). Such felspars and also the quartz show strain shadows. The specimens from other exposures differ only in some minor details.

Pegmatites.

Distinct to these cognate intrusives which are in the main mass, at the borders of the granitic series especially on the southern side where it abuts against and intrudes the Rajgad shales, are found a considerable number of pegmatites mixed up with micaceous gneisses of different modes of origin so intermingled as to render it impossible to map separately the individual components on any reasonable scale. This complex pegmatitic zone extends for a distance of about 8 miles E.-S.-E. and W.-N.-W. with an average width of about 3 miles.

The majority of the pegmatites noticed in the area consists of coarse crystals of white quartz sometimes rounded, coarse platey crystals of felspar generally pink, and crystals of black tourmaline varying in size from small prisms of scarcely ¼ inch long to coarse crystals of 4 to 5 inches in length. The tourmaline is generally found embedded as solitary crystals in quartz, but where pneumatolytic alterations have taken place, bunches of water-clear granular quartz and small rods and needles of tourmaline are found intergrown with each other. Books of muscovite are found in many of the pegmatites in the vicinity of Unchabeda, Malu and Dudhia. Beryl and topaz were also found as rare instances, the former as greenish yellow dull opaque crystals in the pegmatites ½ a mile S.-W. of Malu-Dala and the latter in one of the pegmatites in the vicinity of Unchabeda. Triplite and molybdenite seem to have been noticed as rare constituents.[40]

These pegmatites are all confined to a definite zone bordering the porphyritic granites and show a zig-zag course in an east and west direction. Individually each run can seldom be traced for more than 50 to 100 yards. To the south-west of Malu-Dala they have been mingled with the granitic gneisses in such a way as to obliterate all distinction between the pegmatite types and the granitic gneisses for purposes of mapping. The whole region has

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[40] E. J. Beer, *op. cit.*, pp. 112 and 114.

become a complex gneiss in which the coarser portions look like pegmatites, and the finer like biotite granitic gneisses.

This imperceptible gradation of the pegmatites into the coarse grained porphyritic granites, and their traversing across the granitic types at places indicate that they are a set of later differentiated products of the Haveli porphyritic granite series.

Vein-dykes.

Similar to these pegmatites, are a series of veins of quartz-tourmaline rocks of a finer texture cutting across the granites of this zone. These may be regarded as the later differentiated phases of the granitic magma, corresponding to "vein–dykes" of Spurr. (J. E. Spurr, Ore Magmas.)

Some of these veins contain, quartz, tourmaline and a small quantity of felspar, but in most of them the felspar is scarcely recognizable. As a further stage, even the quartz takes a subordinate position, the tourmaline occurring as veins and patches. To the south of Kanta associated with the granite was found a patch of coarse matted aggregate of tourmaline. Along the southern borders of the hill ranges Δ 758 and Δ 772 the mineral occurs in groups of stellate or arborescent growths of minute crystals either dotting the quartz veins or growing along the joint planes in the granite traversed by such veins of quartz. On the eastern boundary of the porphyritic granite near its contact with the crystalline schists to the west of the 9th mile-stone immediately to the north of the boundary stone between Godhra and Dohad, tourmaline occurs as a big vein of 6 inches wide in immediate contact with a milk-white vein quartz both found in the micaceous schists. Another instance was noticed to the north of Khabda tank where thin vein-like runs of tourmaline have been schisted forming a type of tourmaline schist (B/403).

Distinct to the water clear granular quartz in association with the tourmaline, are found a number of milk-white barren reefs of quartz intersecting the crystalline schists, and the various members of the granitic series. These are evidently the latest phases of consolidation of the granitic magma of the Haveli porphyritic granite series, representing the crystallization of the residual liquor during the hydrothermal phase while the water-clear quartz

in association with tourmaline being probably the result of alteration of the felspar due to pneumatolytic changes.

Gunasia Granitic Gneiss.

The three series of granites, *viz.*, the Chelavad, the Sagtala and the Haveli granites have their individual characteristics and are distributed over fairly large areas of the State. But entirely different to all these in outward appearance and texture is a mixture of pink and grey intermingled banded fine grained granitic gneiss forming the hill range of $\Delta 776$ to the south of Gunasia. This builds up more or less a tabular chain of hills with steep almost precipitous sides to the west, and on the east a gentler slope covered over with recent wind borne deposits. The rock is generally bouldery in appearance, fine grained, granular and pink. The outcrops have a general direction of north to N.-N.-W. but at $\Delta 682$ they show an apparent foliation of east and west dipping steeply to the north. The rugged tabular appearance of these hills and the scanty vegetation they support are in striking contrast to the hill ranges of the granites of the other series. When closely examined the apparent granitic rock is distinctly gneissic in texture and is banded, the bands consisting of pink and grey layers of varying degrees of coarseness. This gives a laminated appearance to the rock when strongly developed and at some of the points the bands have been so disposed as to suggest an appearance of cross-bedding. Sometimes thin lenses, 2 to 3 inches long, of grey and pink material alternate with each other. Even in hand specimens this sort of layering can be seen. For instance in B/60, covering a width of six inches, there are six layers of pinkish material each about $\frac{1}{4}$ of an inch wide, alternating with slightly wider greyish layers, but such layers do not run consistently for any long distance. Sometimes there are porphyritic crystals of felspar which are disposed at an angle to the direction of these layers. In such cases the pinkish material seems to have been bent round the phenocrysts and continue its original direction after the obstruction. The flesh coloured and light grey phenocrysts of felspar often stand out on weathered surfaces. Quartz veins are also seen. This gneissic mass occurs as a narrow band of 3 to 4 furlongs wide amidst the coarse grained disintegrated grey granites cut by numerous tourmaline bearing pegmatites.

The slides of this type (B/60 and B/61) show quartz in irregular large patches surrounded by a confused aggregate of broken grains of the same mineral, felspar mostly kaolinised, a few being still clear showing multiple twinning, and scales and flakes of honey yellow mica. Chlorite and garnet are noticed along with a few grains of apatite and iron ores. Though this rock has a different appearance to the rest of the types of granites of Baria, by its mode of occurrence and micro-characteristics I am inclined to regard this as belonging to the same series of eruptive rocks as the contemporaneous dyke rocks of the Haveli granites already noted. The banding may be possibly due to the incorporation and partial assimilation of the quartzites of the crystalline schists.

CHAPTER VII.

Infra-Trappean Rocks (Lametas).

Overlying the Dhanpur schists with a pronounced unconformity and sometimes resting directly on the granitic gneiss are some outlying patches of infra-trappean beds which consist, where fully developed, of a thin series of gritty and cherty limestone, conglomerate, grits and sandstones and thin gritty whitish clay. None of these were found to be fossiliferous in the region. The largest of these patches covers an extent of about four square miles forming the top of the Jhabu plateau. A few insignificant isolated patches capping the quartzite ridges which form the boundary of the State to the east of Jhabu, and another small outlying patch on the summit of the △ 1745 ridge to the north of Khalta are the other disconnected patches of this series. The lithological characters of these beds differ somewhat from place to place and so each individual exposure will be dealt with separately.

THE △ 1745 HILL EXPOSURE:—Forming the summit of the ridge △ 1745 is an exposure of a thin capping of coarse gritty sandstone overlying partly on the micaceous gneiss (Dhanpur schists) and partly on the biotite granitic gneiss. The grit is pinkish or lilac to pale pinkish white in colour and is coarse textured, the grains of quartz being as big as peas. The rock has a number of tubular cavities and when broken across shows hollows or canals of 5 to 6 inches long filled up with quartz (B/222). These are suggestive of the appearance of worm tracks, but on examination they were found to have nothing to do with organic structures.

In microsections one of the specimens examined (B/221), shows rounded grains of quartz either clear or with dusty and hair-like inclusions showing undulose extinctions, some being internally granulated, cemented by opaque material and chert. Jasper also is noticeable in the interstices. Granular magnetite or ilmenite and a rounded grain of deep honey brown rutile are noticeable. There is no calcite in the specimen. Just near the point △ 1745 are found blocks of a coarse textured white grit (B/228) passing laterally into a conglomerate containing pebbles of quartz of varying dimensions which, having sometimes fallen out, have left

cavities of their original shapes. A few of such have been filled up with silica and chalcedony. This whitish grit grades into the pinkish and lilac types. There are no vestiges of limestones here. The exposure is only 3 to 4 feet thick.

JHABU PLATEAU EXPOSURES:—A series of limestones, conglomerates and sandstones scarcely exceeding a thickness of 35 feet in all, is found as a horizontal capping on the Jhabu plateau, overlying unconformably the highly altered micaceous gneiss which dips under the series. To the north-west the topmost member of this series is overlaid by the dark compact basaltic type of the Deccan Traps. Owing to scarcity of sections and the quick and irregular way in which the individual beds vary laterally, it is difficult to make out the true succession of the series of beds. As worked out from piecing together the positions of the scattered outcrops the succession of the beds appear to be as follows in their descending order:—

C	Deccan Traps.	
B	Pale bluish grey or whitish indurated gritty clay with chalcedonic veins.	1 foot.
	Brick-red friable earthy sandstone. Purplish friable argillitic sandstone. Brown and yellow mottled sandstone.	8-10 feet.
	Conglomerate with pebbles of quartz and quartzites (Local).	
	Mottled brown earthy limestone. Calcareous grit. Gritty limestone. Main mass of limestone with patches of jasper and chalcedony passing laterally into a limestone conglomerate (very variable).	10 feet.
	Friable greenish micaceous quartzite (?)	
A	Micaceous schists of Dhanpur.	

Omitting minor variations, the infra-trappeans of Jhabu may be grouped into,

Sandstone	10′
Conglomerate	2—3′
Limestones	20′.

Limestones:—Forming the topmost contour of the western edge of scarp of the Jhabu plateau is found the main mass of the limestone which winds along like a snake for a distance of 4 or 5 miles from the spot about ½ a mile north of Δ1230 east of Sajoi, to a point about a mile W.-S.-W. of the Jhabu tank where it thins out and disappears. Owing to the dense jungles and the nature of the ground where the limestone outcrops forming the brinks of precipitous gorges, it was not possible to examine the sections continuously from point to point. As traced along the limestone is found to be very variable in character, being conglomeratic in places and homogeneous in others. Half a mile due E.-N.-E. of Pau underlying the brick-red sandstone which forms the rim of the gorge, the limestone bed partakes the character of a conglomeratic type consisting of large and small pebbles of quartz in a calcareous and gritty matrix. This passes laterally into a more homogeneous non-pebbly impure limestone resting unconformably on the calcified micaceous gneiss. At the junction line between the limestone and the calcified micaceous gneiss a group of caves have been cut under, showing clearly the schisted micaceous rock dipping at 25° beneath the horizontal non-foliated calcareous mass. When these beds are traced E.-S.-E. to the top of the gorge south and south-east of Δ1465 the sandstone almost thins out, being exposed only as a narrow band bordering the trap while the limestone widens out, gets more homogeneous and less pebbly, such of the pebbles as are still noticeable being largely composed of rounded quartz. Along this part the limestone varies in colour from pale lavender grey to bluish or violetish grey containing nodules of jasper, chert and chalcedony. In its lower portion near its junction with the micaceous gneiss the type forms a handsome mottled green siliceous limestone with thin veins of calcite. This is seen as harder bouldery kernels amidst the disintegrated pebbly soil. The limestone bed is overlying a thin layer of highly friable greenish micaceous grit or quartzite (B/183, B/258), spotted pink and dark green, suggestive of decomposition of grains of garnet and scaly chlorite. The underlying rocks are the micaceous gneisses of the Dhanpur schists.

Proceeding further south and south-east along the gorge section, the limestone to the west of Jhabua is found as a dull mottled brown and purplish grey type, earthy looking and spreads laterally into the village exposed there along the water courses.

W.-S.-W. of the Jhabu tank the limestone thins out giving place to conglomerate and mottled brown sandstone.

Conglomerate:—Apart from the calciferous conglomerate noted already, is another with a siliceous matrix forming altogether a distinct bed. The outcrops of this appear to be overlying the limestones, but in none of them was I able to discover any pebbles of the limestone. About 6 furlongs E.-S.-E. of Δ1465, a little south of the cart track from Kanakua to Ambli, is exposed along a small water-course a thin bed of conglomerate. This contains pebbles of white quartz; pinkish, deep pink and brownish yellow quartzite; and nodular chert and jasper cemented with a gritty jaspery siliceous matrix. There were no limestone pebbles in this. Examined in the microslide (B/251), the specimen shows rounded grains of quartz cemented with jasper and chalcedony. There are no crystals of calcite or granular carbonates in the slide. Patches of similar conglomerate were found at spots about 4-5 furlongs W.-S.-W. of the Jhabu tank and in the projecting spur E.-S.-E. of Δ1548 at the south-western extremity of the infra-trappeans.

Sandstones:—The conglomerate grades upwards into the coarse textured grit and brownish coarse sandstone. The latter is well exposed in the village sites of Jhabu and Kanakua. It is slightly variable in colour and character in its different exposures. At Jhabu the sandstone is dull reddish-brown streaked occasionally with veins of opal and chalcedony. W.-S.-W. of the Jhabu tank this brownish sandstone is mottled yellow and white. At Kanakua and its adjacent parts the sandstone is pinkish brown in colour. The exposure about 4 furlongs N.-N.-W. of the Jhabu tank, shows characteristically the honey comb or fretted structure and also suncracks (Plate 12, Fig. 1). Here it is somewhat finer grained and earthy.

Clay:—To the south of the Jhabu tank is a thin bed, not more than a foot in thickness, of gritty mottled indurated clay, veined by chert and chalcedony. It is local and patchily distributed, and is found apparently overlying the sandstone as a thin capping. Material very similar to this mottled cherty clay has also been formed by silicification of the weathered product of the micaceous gneiss, but this could be differentiated from the "Lameta" clays by its position and by its containing bronzy or brown flakes of mica.

The other exposures of the infra-trappean beds are found as isolated patches on the high ridges which form the eastern boundary of the State. For the most part they occur as mere surface remnants not even easily identifiable. On the Singsar plateau, and on those to the west and north-west of Bilia forming the Δ 1474, the type found is an indurated white or slightly mottled quartzitic sandstone associated with and overlying a wide spread of conglomerate similar to that of the Jhabu plateau. This conglomeratic bed is well exposed along the northern flanks of the Singsar plateau. To the S.-E. of this, the highest point of the boundary ridge Δ 1597, exposes impure mottled cherty clay in fragments containing dots and streaks of chalcedony and opal. There are no definite solid exposures here and but for the occasional fragments of the remnant blocks of conglomerates, the clay bits might have been passed over as residual weathered products of the underlying rocks.

The following descriptions of the microslides of the various specimens will indicate the textural characteristics of the different types of these infra-trappean rocks.

Limestones :—B/184. Greenish mottled type, compact and granular. The slide shows granular carbonates of very fine to medium texture, in portions occurring like concretionary layers or coronal sheaths around grains of quartz (Plate 20, Fig. 1).

B/252. Pink and grey mottled or concretionary limestone showing at surface dendritic growths of black manganese ores. The slide shows micro-crystalline granular carbonates, containing a small proportion of well-rounded quartz mostly clear and showing strain shadows, a few small patches of brownish chlorite, and small spongy grains of the dark ore. Calcite and jasper occur as small veins replacing the rock.

B/253. Purplish grey cherty limestone, streaked brown and showing blebs of blue opalescent quartz. This was taken immediately west of the above specimen. The slide of this shows rounded grains of quartz of variable dimensions and roundish areas of granular aggregates of carbonates cemented with almost irresolvable calc material. This cementing material at its borders edging the quartz has secondarily crystallised into granular carbonates. There has been some secondary calcification as is clearly seen from the granular calcite filling veins and branching cavities.

B/254. This was obtained very close and immediately west of B/250. In its general appearance it is very similar to that, is more siliceous and has patches of pinkish jasper. The slide resembles that of a calcareous grit having rounded grains of quartz cemented with calciferous material. Honey brown to pinkish jasper occurs as individual grains, but not as a cementing or vein material.

B/256. Pale violetish grey limestone, concretionary having opal, chalcedony and jasper, some of them edged with a rim of apple to deep green earthy celadonite (?). The slide shows as usual rounded grains of quartz cemented with crypto-crystalline calciferous material. There has been a certain amount of secondary calcification. This specimen was taken from the limestone outcrop by the side of the cart track about ½ a mile S.-S.-E. of △ 1465.

B/263. The dull earthy brown limestone. The slide of this specimen is almost opaque showing brown stained cloudy calciferous material and some granular carbonates filling up irregular lacunæ.

B/257. This was selected from the lower zone of the limestone band near its junction with the Dhanpur schists. The type is a handsome mottled siliceous calciferous rock showing in section grains and plates of calcite and granular quartz. The texture is that of a quartzite and the calcite occurs here not as a fine cementing material but as coarser crystals resulting from infiltration of calciferous solutions.

Conglomerate :—B/251. In the field the type of this appears like a coarse siliceous conglomerate having pebbles of white quartz, and brownish red and yellowish quartzite cemented with finer grains of granular quartz. The slide shows rounded grains of quartz of variable dimensions, some clear and regular, others dusty and internally granulated. Most of the grains show strain shadows. These are cemented with patches of red brown jasper edged with chalcedony.

Grits and sandstones :—B/261. Cream coloured indurated coarse textured sandstone or grit, overlying the conglomerate from the outcrop about 3 furlongs S.-E. of △ 1474 on the boundary hills. The section of this specimen shows mostly of rounded

grains of quartz of more or less uniform dimensions, clear or dusty, cemented with pale brownish jasper. There is no calcite in the slide.

B/221. Pinkish grit got from the exposure of Δ 1745. The slide shows rounded quartz of different dimensions cemented with impure silica. The quartz grains are quite similar to those of the rest. There is a grain of honey yellow rutile, and brownish jasper in the slide, but no calcite.

The exposures of this series of rocks in spite of their non-fossiliferous character, appear to me to be the true fluviatile and esturine deposits of infra-trappeans, in all probability corresponding to those classed as " Lametas " which so very conspicuously outcrop further south all along the margins of the Deccan Trap in the lower Nerbudda valley. In fact, these might be the outlying remnants of the bigger exposures to the north-west of Jobat mapped originally as " Bagh and Mahadevas " by Blanford (vide *Mem. G.S.I.*, Vol. VI, Plate 1) and subsequently as Lametas and Nimar sandstones by Bose (see map 3, pt. 2, *Mem. G.S.I.*, Vol. 21). The patch on the Δ 1745 ridge might be the outlier of the exposure forming the ridges Δ 1850, to the west of Kathiawar, mapped as Nimar Sandstone (see map 3, *Mem. G.S.I.*, Vol. 21 cited above).

Mode of Origin.

Regarding the mode of origin of some of the Lameta limestones there has been a difference of opinion. The work of Drs. Fermor and Fox (see *Genl. Rep. Rec. Geol. Surv. of India*, Vol. XLIII, p. 32) in the Chhindwara district has shown that the thin Lameta formation of that region intervening between the Deccan Trap and the underlying gneiss is for the most part, " a rock of chemical origin formed by the silicification or by the calcification of the underlying gneiss " every gradation being found from a fresh porphyritic gneiss to a typical siliceous limestone to be distinguished in no way from the Lameta limestone of other parts of India. As Dr. Fermor found that the limestone of the Lameta ghat itself shows evidence of secondary calcification he is inclined to regard most of the limestones of the formation as of chemical origin, the calcification and silicification of the Lameta sediments when present being ascribed to solutions derived from the overlying Deccan Traps, being thus of post-trappean period.

The possibility of the Lameta limestones having been formed by the superficial replacement of the gneisses prior to the eruption of the Deccan Trap and the deposition of the sedimentary Lametas, has also been noted indicating the probability of the calcification and silicification of the gneiss being of different periods (*Rec. G.S.I.*, Vol. 43, Pt.1, p. 33).

Conclusions similar to those of Drs. Fermor and Fox were arrived at by Mr. Hallowes,[41] from an examination of some calcareous beds found between the gneisses and the Deccan Trap in Hyderabad.

But the finding of the Dinosaurian bones by Dr. Matley[42] in the horizon of the main limestone band of the Lametas at Jubbulpore throws a considerable doubt regarding Dr. Fermor's conclusion on the metasomatic origin of the Lameta limestones in general. By a detailed examination of the Lameta exposures at Jubbulpore Dr. Matley has come to the conclusion that the main limestone band is of an ordinary sedimentary origin.[43]

The Lameta limestone in the Bheemalgundi area (Chhindwara district) regarded by Dr. Fermor and others as a typical representative of metasomatic origin formed subsequent to the eruption of the Deccan Trap has been considered by Mr. Sampat Iyengar as mainly of sedimentary origin.[44]

In view of these conflicting conclusions, it is necessary to examine whether the Jhabu "Lameta" limestone is actually a sedimentary deposit or a secondary rock formed by metasomatic replacement.

Provisionally having the metasomatic theory of origin as a working hypothesis it might be examined as to how far such a view would satisfy the observed conditions in this region.

(A) Let us take the view of the post-trappean replacement:—

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[41] K. Hallowes, *Rec. Geol. Sur. of India*, Vol. XLIX, Pt. 4, pp. 220-22.

[42] C. A. Matley, *Rec. Geol. Sur. of India*, Vol. LIII, Pt. 2, pp. 153-157.

[43] C. A. Matley, *Rec. Geol. Sur. of India*, Vol. LIII, *op. cit.*, pp. 162-163.

[44] P. Sampat Iyengar, *Rec. of the Mys. Geol. Dept.*, Vol. XX, Pt. 2, p. 74.

(1) An examination of the traps of the surrounding areas, shows that calcite is not their prominent constituent either as amygdales, vein infillings or as one of their promiscuous alteration products and as such it is doubtful as to how far it would have been possible for this fairly large mass of limestone to have been formed by the replacement of the underlying rocks by calciferous solutions derived from the trap.

(2) If calcification had been of post-trappean period the maximum change would have been found in the topmost members, diminishing gradually downwards. On the other hand, the sandstone beds directly beneath the trap are not in the least calciferous.

(3) About 5 furlongs to the N.-W. of the point $\triangle$1230 where the edge of the trap strikes obliquely transgressing the tapering end of the limestone band, the trap has become a highly calciferous hybrid rock, by assimilating a part of the limestone, thereby showing that the limestone existed as such prior to the eruption of the trap.

(B) Similarly, the region does not afford any evidences to support the view of the pre-trappean calcification either. The limestone is overlying unconformably the crystalline micaceous gneisses of the Dhanpur region and if there had been any pre-trappean replacement it is this rock which should show the greatest alteration, the calciferous solutions for its replacement being derived from the leaching out of its calciferous contents. The micaceous gneiss in the weathered regions shows veins of nodular kankar. In some of the stream beds to the east of Jhabu are also found occasionally massive blocks of travertine. Near Umria, in the micaceous gneiss is again a vein of pure calcite. But these are all in disconnected areas, irregularly disposed and do not in the least resemble the siliceous limestone of Jhabu, nor do they form distinct massive bands like that. There are no gradational stages from remnant patches of the micaceous gneiss in the limestone to the typical micaceous gneiss with veins and stringers of calciferous material as would have been the case if it had been replaced by calciferous solutions. The limestone is quite distinct from the underlying rocks and has got a definite horizon of its own. At a few points, it has no doubt an indistinct blended contact with the underlying

micaceous gneiss, but this is due to later secondary infiltration of calciferous material leached from the limestone itself. Therefore there are no evidences to regard the main mass of the limestone as formed by the metasomatic replacement of any rock either during the pre-trappean or post-trappean period.

The limestone in spite of its variable character occupies a definite horizon underlying, probably with slight local unconformities, the infra-trappean grits and conglomerates (Lametas), and overlies with pronounced unconformity some one of the members of the crystalline schists of the area.

Most of the specimens examined under the microscope, show fine granular or dusty carbonates cementing well rounded grains of quartz, resembling in every respect the texture of a calcareous grit, or gritty limestone of sedimentary origin. A few show veins containing coarser crystals of calcite formed by crystallization from infiltrating solutions, the latter in all probability being leached from the limestone itself.

That the micaceous gneiss underlying the limestone has been the source of the calciferous material for the formation of the "Lameta" limestone of Jhabu is most probable, but the lime leached from that has not been redeposited along fissures in the rock itself, but has been carried in solutions by streams and rivers along with the dislodged disintegrated transported pebbles of quartz and quartzites, and has been deposited under favourable conditions either as cementing material around the larger grains and pebbles or as a fine precipitate mixed up with smaller grains of quartz just in the way of an ordinary sediment. It is not the circulating solutions within the mass of the micaceous gneiss which has replaced the rock to form the limestone.

But the material for the formation of the "Lameta rocks" has not been transported very far from their source. This is evident by the peculiar characteristics of the individual grains and dislodged masses. An examination of the microstructure of the constituents of the grits and conglomerates reveals that most of the grains of quartz are internally granulated. That is to say, the grain of quartz subjected to severe strain or crushing has developed numerous fractures, but has still retained its original size without being disintegrated or broken up into separate particles. This could only be explained by assuming that either

the grits were subjected to severe post-Lameta crustal disturbances for which there is no evidence in the area or that the disintegrated grains with such fractures which formed the source of the Lameta grits were not subjected to sustained or long continued abrasive action which should have been the case if they had been transported very far from their source. Most of these grains in the microslides look exactly like those seen in the slides of the adjacent Baria quartzites.

In some of the exposures the behaviour of the "pebbles" in the conglomeratic limestone is also peculiar. In addition to a few being perfectly rounded and smooth, there are many which are angular and of diverse shapes and sizes. Amidst such in the bed of the streamlet flowing N.-W. from Jhabu are found even bands of 8—10 feet long. These huge detached bands are neither rounded nor water-worn. They retain still interlacing sets of strain fractures and joints dividing the mass into irregular polygonal blocks.

These "pebbles" or bands of quartzite in the limestone matrix are exactly similar to the quartzites outcropping on the ridge immediately east. It is clear that such detached blocks have been cemented almost near the spot wherefrom they might have been dislocated.

Therefore despite the absence of fossils, the "infra-trappean" rocks of this region do show definite indications of sedimentary deposition, and very probably they have been formed in shallow estuaries or river mouths in several detached areas. It is only on the Jhabu plateau the Lameta rocks show their full development. On the Δ1745 hill exposure there is only the sandstone without the underlying limestone, and at Sejawara, a place about 6 or 7 miles away from the borders of the Baria State, the cherty limestone is directly overlaid by the trap without any intervening sandstone.

But apart from these definite sediments, in the Jhabu region in association with the crystalline schists and underlying the Deccan trap, there are also some types of rocks formed otherwise, simulating in a way the appearance of these true sediments, when by a cursory examination they can be easily mistaken for the true "Lametas" on account of their position. Of such instances of the "Pseudo-Lametas" the following may be mentioned :—

(1) Near the southern edge of the trap on the ridge about ½ a mile east of △1396, the micaceous gneiss where overlain by the trap has been altered beyond recognition. The rock is impregnated with veins of calcite and chalcedony and has developed garnets (B/266), being converted into a cherty calciferous micaceous schist.

(2) About ½ a mile west of this point, *i.e.*, 1 to 2 furlongs south of △1396, the micaceous gneiss close to the trap is altered into a non-descript cherty calcareous rock for about 5 to 6 feet from the line of contact.

(3) In the neck of the land connecting the two hills, that of △1372 and the one to the south of it, are noticeable remnant patches of calcified schists.

(4) Further north in the vicinity of Phulpari immediately beneath the vescicular trap is a thin band of almost pure greyish white crystalline limestone (B/311-312), overlying the schists. This outcrop would create a doubt whether it is actually a true or pseudo-Lameta limestone. This is not overlaid in the region by the sandstones and both laterally and downwards passes into nodular kankary material occurring as patches in the micaceous gneiss, and therefore in all probability it may be a contact alteration of the pre-existed impure kankar-like calciferous segregations, due to the outpouring of the Deccan trap.

In the first three instances, the silicification and calcification are of post-trappean period, and in the fourth the calcification had probably taken place prior to the eruption of the trap.

(5) About a mile S.-S.-W. of △ 1372, the trap abutting west against the limestone and cutting it off has become highly calciferous. On account of its ash grey colour, and easy effervescence with dilute hydrochloric acid, the type could be easily mistaken for a limestone. But a closer scrutiny reveals that the outcrop of the rock has areas suggesting the appearance of phenocrysts and amygdular infillings. The micro-slide of the specimen (B/268) shows it to be highly calcareous, containing veins and streaks of calcite in a decomposed glassy ground showing grains of magnetite and small white lath shaped crystals of felspar (Plate 20, Fig. 2). Here by assimilation of the pre-existing limestone, the trap has become a highly calciferous hybrid rock which might be mistaken for an impure limestone.

(6) In addition to these instances wherein calcification has been due to extraneous sources of the lime, there are one or two cases in which this process has taken place by the leaching of the lime contents from the limestone itself and its re-deposition along the tiny cracks and fissures of the limestone mass or in the underlying patches of the friable quartzite. The latter type, that is, the calcified quartzite, might again be mistaken for a true siliceous Lameta limestone.

Instances like these of mere petrographic interest might be multiplied, but the object sought for is to show that they have nothing in common with the mode of origin of the main mass of the limestone, and as a class such secondary rocks stand quite apart from it.

It is interesting to note that about ½ a mile S.-E. of Δ 1465, by the side of the cart track, underlying the siliceous limestone is a thin patch of highly friable soft greenish micaceous grit, spotted mostly pink and bright green, already referred to. The green colour is very promiscuous when the specimens are wet, but gets dulled into a pale greyish green tint on drying. By its position underlying the infra-trappean limestone, and by its general characteristics it seems to have a striking resemblance to the "Greensand", the lowest member of the Lameta group in the Jubbulpore area as noted by Dr. Matley.[45]

This patch is resting in this area directly on the crumpled micaceous gneiss of the Dhanpur schists. In the field it was highly doubtful whether it formed the lowest member of the infra-trappean group or the highest member of the Dhanpur schists. As this did not form any pronounced bed *unconformably* overlying the micaceous gneiss, I regarded it as a finer grained variant of the friable quartzites of the Dhanpur schists, and its green colour as due to infiltrations from the overlying trap.

The specimens of a small inlier of the pink brown quartzite in the Deccan Trap region, taken from about ½ a mile east of Δ 1291, when examined under the microscope show a very great similarity to typical ferruginous sandstones. The quartz grains are rounded and rarely sub-angular and are cemented with deep red hæmatite. They do not show well pronounced strain shadows or the

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[45] C. A. Matley, *Rec. G. S. I.*, Vol. LIII, *op. cit.*, p. 144.

internal granulation characteristic of the members of the quartzite series. The slide (B/286) showed some resemblance to those of Lameta grits, but still in the field and in specimens, the type is in no way different to the pink quartzites described under the Baria quartzite series, and was mapped as such.

Apart from such doubtful instances, the "Lameta group" of the eastern parts of Baria have their distinguishing characteristics, and not only the grits and conglomerates, but even the siliceous limestones might be regarded as of true aqueous formations.

CHAPTER VIII.

Deccan Trap.

Overlying at some parts the brick red sandstone of the Lameta series of Jhabu and at others directly the crystalline schists are a series of basic basaltic flows. These form but small outlying branches of the main mass of the Malwa Trap (Deccan Trap) which overspreads huge areas in the lower Nerbudda valley. As seen in this area, the basalts are found to be dark coloured compact rocks, either homogeneous or porphyritic showing coarse phenocrysts of felspars. In many of the outcrops, the felspars are seen as long laths, or platey crystals of olive green or resin brown colours, pearly in lustre. Vescicular, scoriaceous and amygdular types are also represented.

The traps outcrop as two conspicuous bands in the eastern part of the State. The present southern extremity of the western band forms the hill Δ 1465 to the west of Katu. Perhaps this band had extended much further south as could be made out by the occurrence of remnants or vestiges of outcrops here and there in the Jhabu village. From Δ 1465 hill, the trap is traceable for a distance of about 4 miles north-west up to and forming the plateau region of Kanajhar hills, the northern termination of which stands abruptly like a truncated wall against the low grounds of the crystalline schists.

The eastern band, longer and more continuous enters the State boundary near the northern end of the Chilagota village and continues northwards forming the eastern borders of the Dudhia and Randhikpur mahals passing away far beyond the borders of the State. This exposure runs for about 15 miles in the State with a width of 3 to 4 miles within its borders, projecting finger-like into the crystalline schists at the western edge. Almost all the river and stream channels cutting through this trap region expose the inlying older crystalline schists. To the west of Δ 1249 there is a small solitary outlying hill of the trap amidst the pinkish quartzites.

Altering the underlying rocks especially the micaceous gneisses by silicification and calcification, the trap has converted

them at some places into non-descript types of impure cherty calciferous rocks already referred to under Lametas. Sometimes the ferruginous solutions infiltrated from the trap have acted as cementing material to the granular quartzites underlying, converting them into ferruginous sandstones or quartzites. In fact a change of colour of the quartzite through this agency is conspicuous all along the western borders of the trap where the quartzites are seen as of yellowish, pale pink brown, and deep pinkish brown tints according to the degree of hydration of the contained iron oxides.

But the contact effects of this trap of more practical interest is that they have induced a peripheral slatey cleavage in the underlying micaceous quartzites or grits in the village site of Kamoi.

Zeolites consisting chiefly of heulandite are found as amygdular infillings in the vescicular and scoriaceous beds. To the south of the small tank on the Δ 1357 plateau are found amygdales of transparent quartz, very pale coloured amethyst, chalcedony, agate and opal.

The traps of this region consist essentially of labradorite tinted superficially an olive green or resin brown, small dark grey granular or platey pyroxene and a sprinkling of iron ores. Brown opaque bandings of palagonite and green earthy glauconite or celadonite are seen mostly in the ashy and amygdular varieties, the latter as infillings or lining the vescicles. Near Δ 1465 the trap is highly vescicular, the vescicles being filled by a granular brittle resin brown mineral which could only be picked with considerable difficulty as minute grains from the vescicles. Sometimes these vescicles are filled with calcite.

In their microsections, most of the types show a microcrystalline texture without any perceptible interstitial glass, the groundmass consisting of felspar laths, augite and granular iron ores.

The chief characteristics of the constituent minerals as studied by an examination of a number of microslides from different outcrops may be summarised to be as follows :—

Felspars :—The microlites in the ground mass are in most of the specimens lath shaped, simple twinned showing an extinction angle of 0° to 4° as measured from their long axes, corresponding to

oligoclase or oligoclase-andesine. In a few cases as in B/255 they show a sort of flow structure. They are prismatic or squarish in section, (B/236). Those which form porphyritic crystals are in large plates generally showing albite twins, combined rarely with carlsbad type. They are generally fresh without any inclusions, but some show schiller-like inclusions of iron ore (B/269 and B/285). In B/198 the big porphyritic crystals of labradorite have small veins of chlorite and central patches of calcite. In B/267 one of the felspar crystals showing imperfect cleavage has two rows of bead like inclusions almost parallel to the vertical axis. In their relations to augite though they do not show a typical ophitic texture generally, in some a sub-ophitic texture is seen (B/199).

Pyroxenes :—These show the greatest variations in colour. In B/198 one set is purplish pink and very slightly pleochroic. These are clear and unaltered. There is another set of distinct brownish yellow type, slightly pleochroic changing in colour from honey brown to pale yellow. This is usually surrounded by iron ore grains which are altering into hæmatite or limonite. The mineral is not well cleaved but where cleavage traces do occur they seem to be at 90°. It is rather irregular in shape or granular, having its refractive index and double refraction higher than the normal pyroxene. It alters in places into deeper brown distinctly pleochroic basaltic hornblende. In its optical characters this species corresponds to schefferite.

In B/287, the pyroxene is purplish blue, in B/269 and B/270 it is purplish grey and in B/269, there are also greenish and greenish yellow varieties. All the strongly coloured varieties (non-pleochroic) are surrounded with or are amidst iron ore grains which are in different stages of alteration. It is doubtful if these colours are deep surface stains or whether they are natural, showing different species of pyroxene.

Among these several types of pyroxenes, I believe those with a distinct yellow or brownish tinge are rather of uncommon occurrence elsewhere.

Among the iron ore grains, magnetite and ilmenite are common, the former in many cases altered to blood red hæmatite. Ilmenite is generally fresh, but in some (B/285 and B/198) it is surrounded by greyish spongy sphene.

In addition to these, some of the compact vescicular types in section show deep honey yellow or honey brown mineral around the vescicles. This brown mineral is highly refracting, irregularly cleaved, non-pleochroic and isotropic, and on account of the difficulty of collecting it, this has not been analysed. It has been doubtfully recognised as helvite.

The amygdular and tuffaceous varieties are dark to light purplish or pinkish grey and generally basic in composition. Lumps of highly vescicular sponge like basic slags were occasionally noticeable especially in the trap exposures near Sejawara, beyond the borders of the Baria State. The vescicular ashy types are filled with zeolites mostly heulandite, and some have a yellowish green or dark green earthy coating resembling glauconite or celadonite in their vescicles. These types show an almost irresolvable or glassy matrix.

The total thickness of the members of the trap series in the region is about 150 to 200 feet. No inter-trappean beds were noticeable in the area and as such it is not possible to break up the series into distinct individual flows. The western band consists for the most part of porphyritic, vescicular and the compact types of the trap without any distinct tuffaceous beds. The eastern band consists at the bottom of a dark grey vescicular trap overlaid by tuffaceous and vescicular beds which in turn are overlaid by the porphyritic and compact types.

CHAPTER IX.

Recent Deposits.

Subsequent to the formation of the Deccan Trap, there have not been any Tertiary deposits in the Baria State. In some of its parts are seen loosely bedded or partially consolidated recent accumulations of peculiar interest which will be noted below.

Soils :—The characteristics of soils and sub-soils which would naturally vary according to the types from which they are derived need not be detailed here. The quartzitic regions are not capped by any thick accumulations of soil. The micaceous schists weather into a light yellowish coloured characteristic loamy soil showing small spangles of mica. The Deccan Trap regions have a very thin cap of bluish clay but the limestones and sandstones for the most part expose the bed rock. The soils of the granitic regions are variable from sandy clays to light or black heavy clayey soil.

Alluvium :—The western borders of the Rajgad mahal has a fairly thick accumulation (8—10 feet) of fine silty or alluvial soil hiding all the underlying formations. Generally it is found as a level stretch capping the low lying grounds. But to the south-east of Gunasia on the ridges forming the eastern flanks of the $\Delta 776$ hill ranges of granite there is a covering of considerable thickness of fine silty soil of at least 50 feet, sloping gently eastwards. This seems to be wind-borne and has covered not only the slope of the hill but even the fairly deep dissected valleys.

Kankar :—Nodules of kankar are found deposited in joints and cracks chiefly in the regions of the micaceous schists and gneisses and also in areas of the granitic gneisses. These are seen along the river banks as interlacing sets of veins or as small nodular lumps mixed up with clayey soil in many parts of the State.

Calcareous tufa :—Just near the Poyelli water-fall are huge massive blocks of spongy calcareous sinter or travertine formed by the precipitation of lime leached from the Poyelli limestones higher up the course of the stream. In addition to massive blocks formed at the surface, the quartzites also have been replaced along their

joints by this material. In the caverns at the water-fall stalactites and stalagmites have been formed, the floor having a massive deposit resembling in shape the shell of a tortoise. Similar calcareous rocks are also found in the stream bed flowing to the north of Kakadkhilla, along the banks of the Hadap river, and in the streamlet east of Jhabu, the lime in the former two places being leached from the crystalline schists and gneisses and in the latter possibly from the "Lameta" limestone.

Shelly limestone :—In the valley between the two quartzite ridges about a mile N.-N.-E. of Δ918 or about the same distance N.-N.-W. of Sakaria, the floor of the valley consists in parts of impure greyish concretionary limestone which contains broken bits and well preserved shells and also some of their silicified casts. These are of fresh water forms (?) consisting mostly of Cerethium, Planorbis, Limnæa, and Littorinella (?). The rock is horizontal, massive and about 3 to 4 feet thick. The shells were picked not only at the surface but even from the interior of the mass. About a furlong or so E.-N.-E. of the outcrop a small water course which flows in this direction seems to have been impounded by a dam, the relics of which are now discernible. It is quite possible that the shells of the gastropods inhabiting this ancient tank might have been carried along with the current and deposited in the area seen. The formation of this type by metasomatic replacement of the schists by the calciferous solutions cannot be suggested as it would be difficult then to account for the presence of the shells. It must be accounted only by some sort of sedimentary deposition. The position of the limestone in the valley along the water course suggests that the lime gone into solution by the disintegration of the micaceous gneiss must have been precipitated here due to some obstruction of the flow, along with the settling of the silt and shells carried by the current. In appearance this type resembles some of the "Pseudo-Lameta limestones" and if it were within the Deccan Trap area would have been probably mapped as such. In portions it has pebbles of quartzites and concretionary infillings of impure calcareous material and granular quartz.

River gravels and conglomerates :—Along the banks of the Panam, the Koliari and the Kabutri, are often found thick accumulations of quartzite boulders, rudely sorted and bedded.

Mixed up with these are found on the banks of the Panam small bits of dark hornblende schists and micaceous gneisses, and in the northern streams flowing through the Deccan Trap region, in addition to the quartzites, pinkish or yellowish coloured pebbles of "Lameta" conglomerates, and pebbles of Deccan Trap. In places these pebbles have been cemented with granular kankar or lime derived mostly from the disintegration of the micaceous schists and possibly by the " Lameta limestones " also, being transformed into rudely bedded conglomerates.

The following are some of the instances noted :—

On the northern banks of the nulla flowing westwards from Jhamri towards Palla is an obscure exposure of a highly weathered micaceous gneiss dipping north at 20°. In addition to its being interbanded with thin runs of quartzite, it is overlain definitely by a massive bouldery dark grey quartzite. This quartzite runs persistently for a long distance while the micaceous schist along its strike passes into the conglomerate having numerous pebbles of dark grey trap, a few of the dark grey quartzites and some of the pinkish grey type. The cementing matrix is calcareous tufa or travertine. The pebbles are mostly rounded varying in diameter from ¼ of an inch to 2 feet. Further west this passes into a shingle bed of pebbles of trap and quartzite unconsolidated. The eastern section of the conglomeratic bed in portions is only calcareous tufa without any pebbles. By its position apparently underlying the quartzite at first it might be mistaken for a conglomerate of some older series, but the presence of the pebbles of the Deccan Trap and the mode of formation of this conglomerate clearly show that the pebbles lying on the micaceous gneiss abutting the banks have been cemented and held in the micaceous gneiss by its own calciferous material leached and deposited *in situ* around the transported pebbles.

The apparent thicknesses of such are variable. It depends to what extent the weathering of the calciferous micaceous rock has proceeded. Sections showing a thickness of 8—10 feet have been noted.

In the river bank to the east of Khera muvada are found sections of highly weathered fine acicular micaceous schist dipping at 45° in which are resting horizontally recent shingle or river

gravel containing pebbles and boulders of quartzite and vein quartz.

Alluvial benches and River terraces:—The ridge Δ576 about a mile or so west of Bharatvara consists of an alluvial bench or river terrace flat topped, but showing a steep scarp towards the Panam river. This is underlain by a bed of recent conglomerate 4 to 5 feet thick having pebbles of different dimensions of vein quartz and quartzites overlying unconformably the micaceous schist. Here again the pebbles resting on the eroded surface of the micaceous schist have been cemented with the lime derived *in situ* by the weathering of the underlying rock. During flood times the alluvia have been deposited in terraces. The ridge east of Δ657 also shows the same feature.

Fault benches:—In the Deccan Trap region, along the northern side of the valley leading towards Nawagam Kheria are found benches or terraces. These are not covered by any alluvial deposit. These appear to have been produced by local slips or faults in the sides of the trap hills of the region. Such post-trappean faults have been noticed to a larger extent by Burton, Fox, and others in the trap regions of Chhindwara area. (See *Gen. Report*, *Rec. of the Geol. Sur. of India*, Vol. 45, Pt. 2, p. 128.)

CHAPTER X.

Economic Investigations.

(A) Mineral Resources of the State.

Indications of some of the metallic minerals are found at certain localities, but none of the deposits are of sufficient promise to be commercially valuable. Many of the economic minerals found are in such small quantities as to be only of passing interest but there are others which though not very extensive deserve some further attention. It has been thought desirable to note the occurrences of all of these irrespective of their quantity, for future references, and so all such as have come under my knowledge have been included here and noted down under the following groups:—

I. Metalliferous minerals:—Gold, Silver, Iron ores, Manganese ores, Copper ores and Metallic sulphides.

II. Minerals used in various Industries:—

(*a*) Abrasive materials: Corundum, Garnet, Tourmaline, Millstones, Whetstones and Hones.

(*b*) Refractory: Mica, Asbestos, Fireclay and Sillimanite.

(*c*) Mineral pigments: Ochery clays.

(*d*) Miscellaneous: Quartz, Felspar, Earth-soda etc.

III. Materials for construction:—Brick, tile and pottery clays, Kankar, Calc sinter, Limestone, Kaolin, Building and ornamental stones.

IV. Rare minerals:—Graphite, Molybdenite, Wolfram, Triplite.

V. Semi-precious stones:—Rose quartz, Amethyst, Agate, Chalcedony, Opal, Beryl, Apatite, Topaz, Tourmaline, etc.

I. METALLIFEROUS MINERALS.

Gold and Silver:—Traces of gold and silver are found in some of the quartz veins traversing the dark hornblendic schists of the Bhanpur plateau. The specimens assayed showed only heavy traces of gold and 3 to 4 dwts. of silver per ton, being thus of almost negligible value to tempt any large-scale expenditure for their further prospecting.

Iron ores:—Jaspery hæmatite is found in small patches capping the limestone in the village site of Poyelli. Loose bits of crystalline hæmatite are also found scattered to a small extent on the outer edge of the Poyelli scarp and the presence of slag near Sursuva indicate that these were once probably smelted. The altered quartz porphyry rock north of Poyelli and also the granitic band to the south of Tokarwa contain magnetite as their accessory constituent. But none of these are of any special importance from a commercial point of view.

Manganese ores:—Psilomelane and wad of low grades are found as fissure infillings among the northern bands of quartzite at a point about 4 furlongs, 10° N. of E. of Δ793. Here along the fault fissure, the rock has been replaced to a small extent by ferruginous and manganiferous solutions, the ore bodies occurring as irregular patches and pockets of varying degrees of purity or as groups of granular crystals or crystal aggregates. As disclosed by the prospecting shaft and trenches which had been sunk on the ore body, the deposit does not appear to be promising. Its position about half way up the steep hill, amidst dense jungle, and its mode of occurrence as thin patches and pockets are not conducive to detailed prospecting or easy location of other bodies of ore if they exist. The working expenditure of this sort of ore body is likely to be very high and at present, it may be regarded as of no commercial value.

Copper ores:—Traces of malachite are found in some of the quartz veins of the Rajgad and Dhanpur mahals. On one of such near Jher, a fair amount of prospecting work has been done. The lode, a cupriferous quartz vein, which is traceable for about 500 feet has been opened out by a series of trial pits, and at its middle a large cross trench passing right through the contact zone has been cut for a length of nearly 300 feet. As seen here the

quartz vein is only poorly impregnated with cupriferous ores. The vein is not more than 3 to 5 feet wide at any part. The picked samples of the lode material do not amount to more than 5 or 6 per cent of the vein rock, and even such do not contain beyond 1 to 2 per cent of copper. Nearby no other lodes of any promise were noticeable. The rest of the occurrences are still more insignificant, being no more than surface stains on an otherwise barren milk-white quartz reefs. Only one in the Dhanpur mahal was impregnated with metallic sulphides referred below. On the whole I do not consider these cupriferous ores worth further trouble.

Metallic sulphides:—Of these only pyrites is noticeable here and there, but generally not in large segregated patches. But on the crest of the ridge ½ a mile S.-S.-W. of Malu Moti is a quartz-felspathic vein stained lemon yellow showing distinct crystals of pyrites: It is of no special interest for its pyritic contents, and though the tests showed it to contain nothing else it is better to get it opened out and ascertain if there are any other sulphides below. From a transported bit of probably the same or similar lode of this area, malachite stains were noticed and so these lodes may be cupriferous in places.

The lead sulphide, Galena, seems to have been noticed beyond the borders of the State, but I was unable to detect any definite indications of that mineral anywhere within the borders of the State.

II. Minerals used in Various Industries.

(A) Abrasive Materials.

Corundum:—A few corundum crystals sparsely distributed seem to have been noticed by Mr. Beer in the granitic region near Kaliakua, a few miles to the N.-E. of Sagtala. This did not come under my notice nor was I able to see corundum deposits of good or indifferent grades anywhere else in the State.

Garnet:—Though this mineral is found as a common constituent of many of the altered rocks, specially the micaceous schists and quartzites, it was not seen in sufficiently large concentrated patches to be easily workable and turned into some practical use. In the northern portions of the Dhanpur micaceous gneiss, to the east and north-east of Sajoi are some exposures showing fairly fresh crystals.

Tourmaline :—I am not aware of this mineral being used as an abrasive. Though it is fairly hard, probably when broken it may not give the sharp angular edges needed. This mineral is found as jet black crystals in fair abundance in many of the pegmatites of the contact zone to the north of Rajgad (*vide* map) in the vicinity of Unchabeda and Malu.

Whetstones and Hones :—Layers of micaceous grits which have been well cleaved, have been quarried to a very small extent in the village site of Kamoi. Similarly some of the bands of fine and coarse felspathic grits on the top of the Pali hill to the north of Rajgad have also been used locally. It is better to get these systematically opened out by a few larger trenches. In addition to their yielding smaller whetstones, the beds may possibly yield larger sized paving slabs of fairly good quality.

Millstones and Rollers :—Excepting the granites, the rest of the rock types of the State as seen at the surface appear to be too soft for these purposes. There is an inexhaustible quantity of these granites and they will be dealt with under building stones.

(B) REFRACTORY MATERIALS.

Mica :—Muscovite is found in books of 1 to 2 inches across as seen at the surface in many of the pegmatites of the contact zone. Some of these pegmatites have been opened out to shallow depths. As disclosed therein it is of a fairly good quality and is colourless or pale reddish brown when seen in thick books. Plates of 5 to 6 inches across seem to have been obtained in some of the pits. This mineral deserves further prospecting on a somewhat larger scale.

Asbestos :—Thin narrow veinules of chrysotile (serpentine asbestos) are found to a small extent in the serpentine marble found exposed in the bed of the big nulla joining the Panam river about ½ a mile south of Gara. As seen in the outcrop they are useless; but the marble itself has some value as an ornamental stone and if that is quarried it will also be revealed if there be any larger workable veins of asbestos.

Sillimanite :—Small acicular crystals of sillimanite occur as microscopic constituents in some of the lower beds of the Dhanpur schists. The mineral forms only about 1% of the total constituents of the rock and was not found anywhere in segregated patches.

Since a larger portion of the outcrop is not within the Baria State it is of no particular use to the State.

Fire clay:—Good deposits of fire clay were not observable anywhere within the State. Some of the pegmatites and granitic gneisses have given rise to patches of kaolin and whitish lithomargic clays. There are some small patches of cherty clay on the Jhabu plateau on the neck of the land leading from Khajuri to the plains towards Kotambi.

(C) MINERAL PIGMENTS.

Very pale coloured yellowish ochery clays are found on the hill near Pali and also at some places in the village site of Chilagota. These are locally made use of. They were not seen in sufficient abundance to be of any commercial use.

(D) MISCELLANEOUS.

Quartz:—Veins of quartz of high degree of purity which in their aggregate form an almost inexhaustible quantity are found in the regions of micaceous schists of almost all the mahals. These seem to have been used locally for the manufacture of glass. Almost all of them are milk-white and are absolutely barren. Very few contain nodules of hæmatite or earthy limonite.

Felspar:—Coarse crystals of pink and at some places white felspars are found largely in many of the pegmatites of the contact zone. Their chief use at present is only as a glazing material in the manufacture of high grade porcelain ware. For this purpose potash varieties are preferred and those of the contact zone appear to be potash bearing.

Earth Soda:—Efflorescent patches of earth soda occur as thin surface coatings on the micaceous gritty schists near Bartanpara, and at many of the stream banks of the Randhikpur mahal. As seen here it is difficult to collect a large quantity at any particular spot for lixiviation. It is reported that no large workable patches are seen in the granitic regions of the southern mahals.

III. MATERIALS FOR CONSTRUCTION.

Clays:—Brick and tile clays of an average quality are found in many parts of the State. On the plateau regions of Jhabu,

Kakadkhilla and Bhanpur, there are extensive deposits of this material of variable texture and character. Some of them may prove suitable for the manufacture of better class bricks (wire cut pressed bricks) and also for making roofing and flooring tiles similar to the patterns known as "Mangalore" tiles. They might also prove to be suitable mixers to the limestones of the State for manufacturing portland cement. Large-scale surveys showing the exact extent and position of these deposits would be needed to ascertain the actual extent and quantity of the material and also to find out whether they are in free or alienated lands.

Kankar:—Small nodular kankar is found as patches along the banks of the streams and nullas in the micaceous schist region at many places.

Calcareous Tufa:—Different to these in character are found massive blocks of calcareous tufa and travertine not very large at any one particular place, but forming on the aggregate a fair quantity. These are not likely to be suitable for ordinary lime making as they are probably hard burning, but I think they will be suitable for manufacturing cement and if the siliceous limestones of the Jhabu plateau do turn out to be suitable raw materials for making cement, then these deposits of calcareous tufa would form valuable accessory sources.

They were noticed in patches at the following places :—

(1) Near the Poyelli waterfall, (2) on the bank of the stream to the north of Kakadkhilla, (3) in the stream bed flowing north and south to the west of Jhabu, (4) along the banks of the Hadap river (more kankary), and in the gorge section of Koliari river to the N.-W. of Salia.

Limestones:—These are of variable character, and may be divided roughly into the following types:—

(1) Crystalline limestone of Poyelli region.

(2) Thin lenticular bands in the granitic gneisses of Sagtala area.

(3) Siliceous limestone of Jhabu plateau.

(4) Kankary or nodular limestone.

The first two types will be dealt with under building stones.

(3) Siliceous Limestones.—Forming the basement member of the "Lameta series" of the Jhabu plateau are exposures of horizontal limestones which are variable from point to point. Some of them have coarse pebbles of quartz and quartzite and others are of the nature of calcareous grits. There are also portions where the lime contents seem to be high and if the latter type exists in larger quantities as it seems to be, it may be found suitable, by proper admixture, for making cement. A large-scale survey showing all these variations to scale, and also a number of analyses of bulk samples would be needed before the deposit can be definitely proved to be a satisfactory zone of raw material for the cement making. As the deposits of clay and some of the other types of calcareous deposits are not far off, the area is a suitable centre for a thorough investigation.

(4) Other types such as the kankary nodular limestone and the replacement cherty limestone also may be found suitable, but as said above these will form only as accessory sources.

Kaolin:—High grade kaolin comparable to Cornish clays are not seen in the State. In fact kaolin is rather rare and where seen appears to be admixed with much of lime kankar. It was noticed at the following spots:—

(1) In the cutting about 100 feet E.-S.-E. of the Gunasia temple forming the cart track leading from the river to the village. The kaolin is found here in patchy pockets traceable over a width of about 150—200 feet and as it is seen again in the cart track to Bhojpar, further south, the total length over which it may be expected to be found will be at least 500—600 feet. But the material is hidden under cultivated lands and its actual extent must be ascertained only by test bore holes.

(2) In the road to Khalta from Dhanpur at another cutting near the N.-E. bend of the river about 4—6 furlongs W. of Δ 928 are patches of kaolinic material, found exposed. The stream bank does not show any good indication, and as the deposit is not well seen its quantity or extent is not ascertainable as it is.

(3) Calciferous whitish clays are found in the village site of Chilagota forming patches and pockets in the micaceous gneiss. Similar materials were found to the south of the village of Chapri under a ridge of soil cap. These appear to be of rather small extent.

River sands:—I might as well mention the sands of the Panam and Ujol rivers which are of varying degrees of coarseness and purity. In some places, especially in the bed of Ujol there are good white sands which may be found suitable for making sandlime bricks.

Building and Ornamental Stones: Building stones:—Granites are the most prevalent among the building stones of the State, but strangely there has not been a single place where it has been quarried here. These granites and granitic gneisses are of diverse types and all of them are not likely to yield good material with equal ease. The coarsely porphyritic granites are generally difficult to quarry and amongst them the pink variants would be much more so than the grey. But many of the outcrops of this State are well jointed, and when once the surface layers are removed some of them should yield by regular quarrying decent sized slabs, and stones.

For purposes of quarrying the following outcrops are the most suitable:—

(1) The greyish banded granitic gneisses in the vicinity of Ankli.

(2) The grey biotite granite on the eastern flanks of the hill Δ987 west of Singedi.

(3) The grey coarse granitic gneiss to the N.-W. of Damavav.

(4) The pink porphyritic granite at the spot about 1 mile N.-E. of Khanpala where it forms a flat low lying exposure seen over a wide area.

(5) The low lying flat exposures on either side of the cart track from Kalidungri to Abhlod.

Besides these, a number of other spots could be selected, but since diverse factors such as the transportation facilities, the distance of the quarries from the markets, and the actual existing demands for them have to be taken into consideration for an enterprise of this kind, those which are situated far in the interior have not been considered here.

Micaceous gneiss:—Next in importance is the gritty micaceous schist or gneiss of the Dhanpur mahal. It is generally in a highly

weathered condition, but to the north of Edalwara, Sajjoi and Pau for some distance, there are bands and layers which are fresh and compact. Rocks, similar to these, form one of the types quarried near Jhalod and they seem to be largely adaptable for carving as seen in the megalithic monuments near many of the village sites. Even at Jhalod the beds seem to be not of uniform grade and it is only by actual testing it has to be seen if the Dhanpur rocks could produce types comparable to those which are at present imported. As seen at the surface, though they do not form handsome paving stones, they may be tried for similar other purposes where neither great strength of material nor perfect elegance is required.

Slatey schists:—In the Poyelli village immediately north of the limestone band are found outcrops of a highly jointed dark bluish grey slatey schist. As tried by quarrying this can be obtained as paving slabs of suitable sizes of 1 to 2 inches thick. But the surfaces of the slabs so got seem to be somewhat unsmooth. Probably the quality may improve downwards.

Greyish green slatey schists of similar character are found further north, in the village site of Jhendri. A fairly large quantity is obtainable here.

Micaceous and felspathic grits.:—The felspathic quartzite of the Pali hill and some of the layers of the micaceous grit in Kamoi are well jointed and break up into regular sized paving slabs when quarried. In the Pali hill the outcrops vary in colour from reddish pink to creamy white and they also vary in texture. The Kamoi outcrops are of a dull pinkish grey colour. Both these places are in the interior.

Lameta sandstones:—Of these only the exposures on the western edges of the Jhabu plateau are worth considering. Owing to the growth of grass and soil cap it is not always easy to locate the exact situations of the actual outcrops and study their character and extent. A layer or band of outcrop seen about a mile or so W.-S.-W. of Jhabu tank forms a handsome mottled yellow and pinkish brown type. There are others which are rather of a dull colour, while some are very friable. Since these are in association with the limestones already mentioned, if the quarrying of that is undertaken for any purpose it may serve, the quarrying of hese sandstones might then be taken up as an accessory adjunct.

Beyond these, I did not notice any well cleaved slatey beds likely to yield thin roofing slates. No doubt here and there, some slatey schists are found, but as their outcrops are not seen to be extensive they have not been mentioned here.

Ornamental stones :—These stones cannot be expected to occur over very large areas. They are confined to small patches of outcrops amidst types of less valuable kinds. Of such the following deserve mentioning :—

The pink *syenitic aplite* found to the south of Kakalpur crossing the nulla between Vau and Lavaria. This is a band of about 4 to 5 feet wide and about 25 to 30 feet long as exposed, but perhaps it continues further.

The medium textured uniform *pink granite* in the river bed between Tokarwa and Goja. Hereabouts are also pink and dark grey granitic types of good colour.

Whitish grey granular limestone:—A band of this rock is noticed in the water course, by the side of a pegmatite on the northern side of the small hill range north of Nadatod. This is traceable for about 30 to 40 feet. There are many other smaller runs in the neighbourhood here and there.

On the Poyelli hill amidst the mass of limestone outcrops are small patches of white crystalline marble and others of different tints. These, as well as the dark grey limestone itself when polished, form useful ornamental stones.

Serpentine marble:—To the north of Tokarwa in the bed of the stream joining the Panam river to the south of Gara is a lenticular exposure of a dark grey serpentine marble. This will take a fine polish.

Green stained marbles of Jhabu :—By the side of the old cart track leading from Dhanpur to the plateau towards Katu at the point about 5 or 6 furlongs almost south of Δ 1463 are layers of limestone handsomely coloured with green patches. In fact, some of the loose material as taken out has been lying about here. This is rather soft and has to be carefully handled.

Pale mauve coloured limestone :—Proceeding further N.-E. to the top of the plateau are patches of pale lavender to pale pinkish violet cherty limestone bands which also form pleasing types. The other types round about here are rather of a dull colour.

White pyroxene rocks :—Two bands of this type were noticed, but both are unfortunately in the dense jungles and are not likely to be of practical use at present. One was about half way up the northern flanks of the hill about 5 furlongs due east of Δ1475 to the south of Ladiawad. This is not far from the Rattanmahal boundary. Another was noticed in the western flanks of the hill about 6 furlongs E.-S.-E. of Sajwan phalia.

Fuchsite quartzite :—This is a handsome greenish chrome-mica bearing quartzite, which but for one solitary small patch was never noticed anywhere else in the State. To the north of Unchisadad there is a big schisted quartzite running east and west of a different appearance to the rest of the quartzites in the State. In this at only one spot was noticed a small patch of the greenish type. As fuchsite quartzite fetches a handsome price, this outcrop must be got thoroughly examined throughout its length to ascertain if there be any more of such green mica bearing portions.

Pinkish mottled quartzite ;—Patches of white and pink mottled micaceous quartzites are found here and there on the top of the long ridge of the boundary hills to the east of Nawanagar. They are suitable for making paper weights.

Porphyritic trap :—Compact black trap with white or stained coarse felspar crystals forms another type which takes a good polish. This is found in the vicinity of Δ 1465 on the Jhabu plateau.

Some of these ornamental types are suitable for inlaying work, and others could be used as handsome paper weights while a few will form when polished very nice flooring stones.

Road metal :—At present quartzites and vein quartz obtained from shallow pits are being used for this purpose. If granite is quarried to any large extent in the State, it is likely to yield better grade road metal. Tough dark hornstones, and compact basaltic traps would also be found suitable for the purpose, but they are too far in the interior.

IV. Rare Minerals.

Most of these are only of scientific interest, being found in small quantities, but their occurrences have been noted for future reference.

Graphite :—This is rare so far as its occurrence in the State is concerned. The peculiar brittle schisted actinolite quartz reefs probably contain this mineral in minute scales here and there, though I failed to detect any. It appears the mineral has been noticed near the village Jhab which I missed seeing.

Molybdenite :—This is also reported to have been found along with cupriferous ores in the Jher workings. As now seen, the outcrops fail to reveal any distinctly recognizable flakes. Even from the material of Jher workings it is found to be almost in microscopic sizes being too difficult to detect.

Wolfram :—This mineral is also noted from the same area but none of the outcrops shows it conspicuously.

Triplite :—This mineral is stated to have been found loose in 2 or 3 places. It is not conspicuously seen. At only one place I noticed it in a pegmatite in the neighbourhood of Unchabeda.

V. Semi-Precious Stones.

Beryl .—Highly cleaved dull coloured yellowish green crystals of beryl are found very occasionally in some of the micaceous pegmatites in the neighbourhood of Unchabeda. They are too much cracked and are not of good colour.

Similarly another solitary instance of its occurrence was noticed where it was seen as bluish crystals in a quartz vein in the village site of Goria about ½ a mile due south of △1219.

Rose quartz :—Rose coloured quartz is found as small patches in the masses of quartz veins in the forest region to the S.-W. of Malu.

Amethyst, etc. :—Pale coloured amethyst, quite clear and transparent, is found rarely as amygdular infillings in the trap region to the south of the small tank of △1357 (Kanajhar) plateau. Crystals of quartz, chalcedony, banded jaspers, etc., are also found here though none were seen of any brilliant colour. The only other mineral which need be mentioned here is the pale greyish white topaz which occurs in minute crystals as one of the constituents of the pegmatite near Unchabeda. As found there it is not of much practical value.

(B) Engineering Enquiries.

While surveying the State, I was struck with the possibility of impounding the waters of some of the streams for irrigational purposes. The conditions at all such spots are not ideal and there might be some obstructions to overcome. Of the many spots seen I think the following require some mention :—

(1) The valley to the west of Ved.

(2) The gorge to the west of Edalwara.

(3) The gorge of the Hadap river near Kesarpur, where the road passes towards Randhikpur.

(4) The gorge of the same river where it passes through the hill ridges to the west of Patangri.

The Patangri Gorge :—Here the river passes through a gorge in the middle of the ridges Δ864 and Δ835. The northern end of Δ864 ridge, *i.e.*, the ridge to the south of the river shows bands of quartzites dipping at low angles of 25° W.-N.-W. forming a dip-slope on that side. Though the exposures are jointed, the joints are not likely to affect the stability of the rock as a firm foundation or its impervious character. If needed they may be suitably protected. On the northern side of the river the ridge shows a local bend and fault, with the dislodging of some blocks. The solid exposures are highly jointed, but the rock is not much weathered. There is a wide gaping fissure of 2 feet which extends into the body of the rock for a little distance in this side. Possibly this may be remedied by suitable precautionary measures, but to be certain of the absolute stability of the rock for the foundation, some very close examination will be needed. Relative heights of the banks to the stream bed seem to vary from 5 to 30 feet. The banks consist of unconsolidated mud and gravel, unstable and likely to collapse. This debris or accumulation of loose stuff is likely to silt up the channel to a certain extent. Emptying into this Hadap river just to the east of the gorge is a streamlet flowing from the S.-S.-E. When the water is impounded the flow will rush up this streamlet and possibly may cut through a channel for itself in the low water-shed and thus divert a main part of the impounded water into the Koliary river, and this will have to be guarded against.

The Kesarpur area :—Here the quartzites are more highly jointed than at the other spot, and the attitude of the beds seem to be not very favourable for yielding a stable foundation. But since the dip directions and their magnitude are not clear, trial trenches and pits will be needed at certain points, for a depth of 10-15 feet below the level of the stream bed to be positive about some of the doubtful factors. This site requires a longer embankment than that to the west of Patangri.

Edalwara :—The catchment area to the river appears at this point not to be very large. As the sides of the hills on either side are pretty steep, a good deal of blasting may be required to cut them into benches for the foundation. But for the doubt regarding the total volume of water which could be impounded here, I do not find any structural difficulties.

Ved :—Further west there is another valley to the west of Ved through which this river passes. This may probably turn out to be a better site, but the length of embankment needed at this spot will be considerably greater than that at the Edalwara gorge.

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* Correction of 2′ E. has been applied for the longitudes as taken from the old topographic maps of 1905 edition.

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EXPLANATION OF PLATES OF MICRO-SLIDES.

Plate 14.

Fig. 1. Dark hornblende schist :—The dark almost opaque patches represent the blue green amphibole, and the lighter areas constitute granular quartz and a few crystals of plagioclase felspars. (B/209.)

Fig. 2. Coarse micaceous gneiss :—The dark platey crystals are honey brown biotite, some enclosing pale pink garnet. These are edged with chloritising blue green amphibole. The lighter areas consist of fine granular quartz and spongy blades of kyanite. (B/274.)

Fig. 3. Secondary pyroxene rock :—The slide shows uralitising colourless prisms of pyroxene, coarse granular crystals of brown sphene and greyish patches of sphenic dust. (B/28.)

Fig. 4. Diopside rock :—Granular and platey colourless crystals are those of diopside, black scales are of honey brown biotite. A few crystals of granular sphene (dark grey) are noticeable towards the edge. (B/216.)

Plate 15.

Fig. 1. Crystalline limestone :—Coarse crystals of calcite showing lamellar twinning, a grain of garnet, and a few grains of colourless olivine (?) are noticeable. (B/144.)

Fig. 2. Serpentine marble :—The dark grey areas showing twinning and cleavage lines are those of coarse plates of calcite. The white areas consist of serpentine showing under crossed nicols relicts of amphibole. The highly refracting grain in serpentine is sphene. (B/172.)

Fig. 3. Dark grey Poyelli limestone :—The wedge shaped crystal in the centre is colourless amphibole and this is edged with fibrous calcite seen as white marginal rim. The rest of the portion consists of granular carbonates. (B/89.)

Fig. 4. Felspathic quartzite :—White granular areas are those of rounded quartz. A twinned crystal of plagioclase is seen in the centre. Pink tourmaline crystals are noticeable as dark granular areas at the edge. The slide shows a certain amount of secondary silicification. (B/419.) × Nicols.

Plate 16.

Fig. 1. Felspathic quartzite :—Shows mostly of rounded grains of quartz (light grey) and a few crystals of tourmaline (dark grains). (B/420.)

Fig. 2. Felspathic grit :—Shows mostly of rounded undeformed grains of quartz clastic felspar (rod like grey mineral at the edge) and opaque iron oxides. (B/422.)

Fig. 3. Micaceous quartz porphyry:—Coarse crystals of granulated quartz, a phenocryst of twinned felspar and platey crystals of biotite (black) are seen in a micro-crystalline ground of granular quartz, mica and iron oxides. (B/418.) × Nicols.

Fig. 4. Sericitised quartz porphyry:—Matrix rock of the Poyelli "conglomerate". Coarse crystals of quartz showing strain shadows are found as phenocrysts along with a few scales of biotite in a micro-crystalline ground consisting of sericite and quartz. (B/99.) × Nicols.

Plate 17.

Fig. 1. Hornstone:—Shows a banded texture consisting of micro-crystalline aggregates of silica (white areas) and almost irresolvable material showing scales of biotite. (B/76.) × Nicols.

Fig. 2. Biotite sillimanite schist (Metamorphosed type of Rajgad shales):—Shows flakes of reddish brown biotite (black) and fibrous bundles of sillimanite (grey) arranged with a schistose texture in a granular ground of quartz. (B/29.)

Fig. 3. Secondary amphibole rock:—Shows a coarse crystal of garnet (in centre), granular quartz (white patchy areas) and dark greenish blue amphibole (black). Epidote, zoisite, and ilmenite which are present are not clearly recognizable.

Fig. 4. Secondary amphibole rock:—Shows blue green amphibole (dark areas spotted white) peppered with quartz, granular quartz, sphene, 2 or 3 crystals of calcite and grains of ilmenite. (B/3.)

Plate 18.

Fig. 1. Baria quartzite (bluish grey):—Shows a fine textured ground consisting mostly of rounded quartz, some showing marginal crystallization of silica, and black patches of hydrated iron oxides and impure dust. (B/1.)

Fig. 2. Baria quartzite (dark grey):—Shows mostly sub-angular and rounded grains of quartz, small scales of muscovite, biotite, chlorite (black patches) and dusty iron oxides. (B/17.)

Fig. 3. Baria quartzite (pink):—Shows rounded grains of white and honey yellow quartz with hæmatite as cementing material. (B/315.)

Fig. 4. Friable quartzite:—The slide shows rounded grains of quartz almost opaque patches (black) of stained micaceous mineral and garnets. Colourless micas are not clearly seen. (B/186.)

Plate 19.

Fig. 1. Deep pink quartzite:—Rounded grains of quartz are cemented with deep red hæmatite (black). The texture resembles that of a ferruginous sandstone. (B/286.)

Fig. 2. Lameta grit of Jhabu:—Shows rounded grains of quartz cemented with jasper. (B/251.)

Fig. 3. Calcareous grit of Jhabu:—Consists of granular quartz cemented with dusty carbonates. The central black plate is that of reddish jasper. (B/254.)

Fig. 4. Siliceous limestone of Jhabu:—Shows mostly of crypto to micro-crystalline granular carbonates, and a few well rounded grains of quartz (only one grain is seen in this fig.). There has been some secondary calcification as is noticeable by the branching vein containing coarse crystals of calcite. (B/252.)

Plate 20.

Fig. 1. Concretionary siliceous limestone:—Shows granular carbonates of very fine to medium texture occurring as coronal sheaths to grains of quartz. The large greyish white grain is quartz and it shows the rim of carbonates. The others are all smaller. (B/184.)

Fig. 2. Calcified trap:—Shows a compact almost glassy trap veined by carbonates. The white band represents the veining of calcite and the haze on either side of it is due to the disseminated grains of carbonates. The clearer squarish areas are those of felspar crystals. (B/268.)

Fig. 3. Compact trap:—Shows microlites of felspar, augite and grains of ilmenites. (B/285.)

Fig. 4. Porphyritic trap. Shows a micro-crystalline ground of felspar, augite and iron ores, with porphyritic crystals of labradorite. (B/198.) × Nicols.

N. B.—Numbers in brackets refer to Registered Nos. of slides preserved in the Mysore Geological Department, Bangalore.

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PLATE 1

Fig. 1. Dark hornblende schist (grey) veined by faulted pegmatite (white). In the stream bed west of Padalia. (*Sledge hammer handle is 3′ long.*)

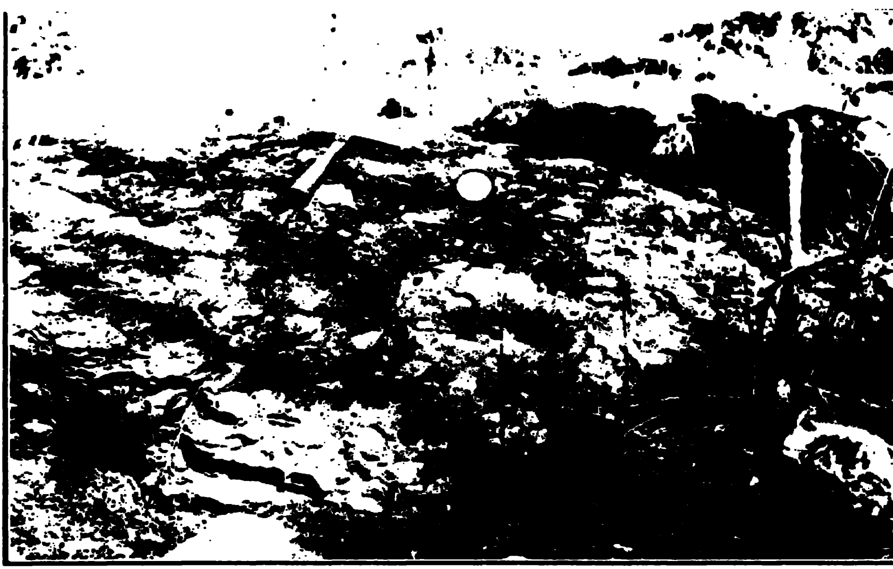

Fig. 2. Poyelli "Conglomerate". West of waterfall. (*Hammer handle is 15″ long.*)

Photos: B. Rama Rao.

PLATE 2

Fig. 1. Poyelli " Conglomerate ". North of Gandhra.

Fig. 2. Formation of " pebbles " (pseudo-conglomerate) in quartzites. West of Punakota.

Photos : B. Rama Rao.

PLATE 3

Fig. 1. Peculiar buttressed spheroidal weathering of quartzite.
On △ 1357 range dip-slope side, west of Edalwara.

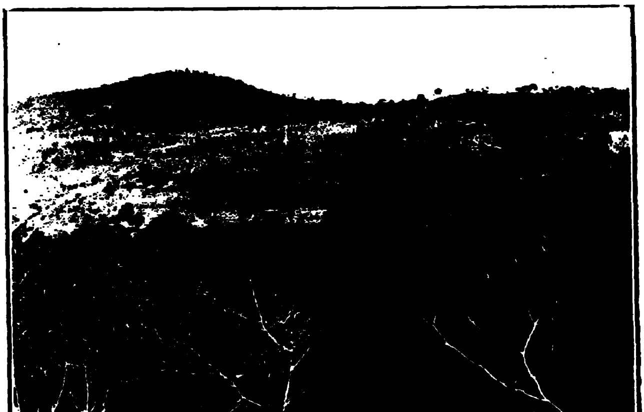

Fig. 2. Columnar weathering of quartzite.
In the background is an expansive flat of plateau quartzite capped by Deccan Trap hill. Near Mander.

Photos : B. Rama Rao.

PLATE 4

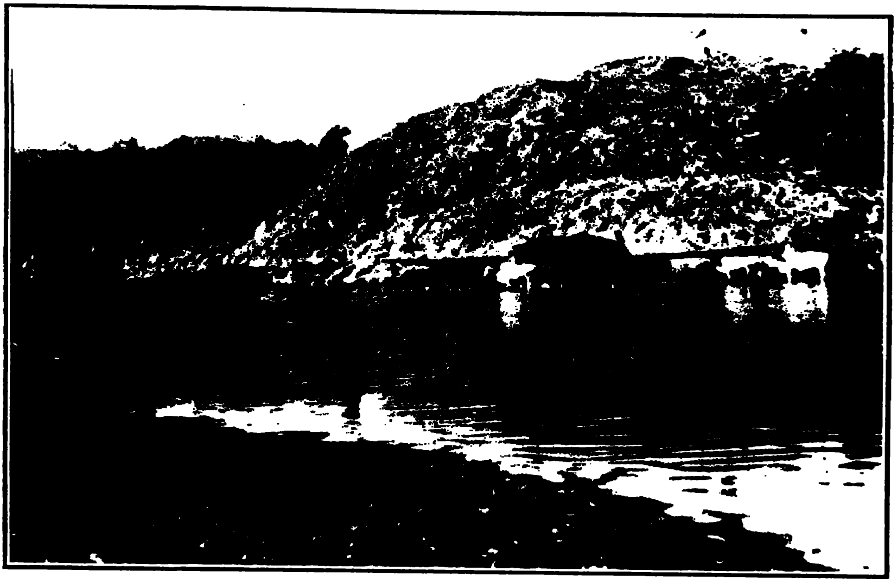

Fig. 1. Massive quartzite flanking the river Hadap. North of Umria

Fig. 2. Levelled summit of pink quartzite.
The △ 928 hill near Mander. View, N.-N.-E.

Photos : B. Rama Rao.

PLATE 5

Fig. 1. Dip-joints in quartzite. ½ mile S.-W. of Kundawara.

Fig. 2. Dips in Baria Quartzite. In the river bank west of Nawanagar.

Photos : B. Rama Rao.

PLATE 6

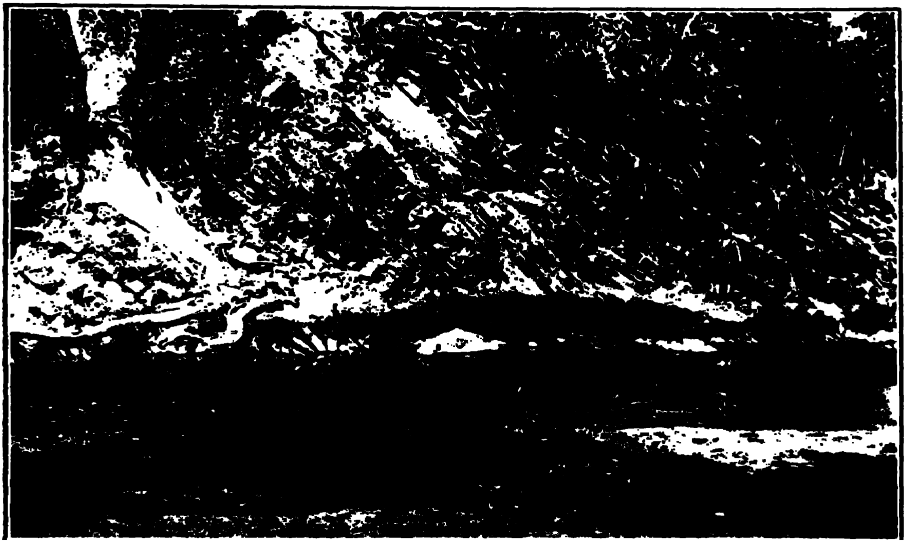

Fig. 1. Interbedding of quartzite and micaceous phyllite, near Nawanagar.

Fig. 2. Bedding in sillimanite quartzite, in the river bank. ½ mile south of Ladiawad, Khalta Valley.

Photos : B. Rama Rao.

PLATE 7

Fig. 1. Sun-cracks in micaceous quartzite. In the river bed north of Pata.

Fig. 2. Wave-made ripple marks in the micaceous quartzite. Exposed in the stream bed east of Bandibar.

Photos : B. Rama Rao.

PLATE 8

Fig. 1. Brittle quartzite overlaid by micaceous quartzite.
In the bed of the stream, S. of Polisimal.

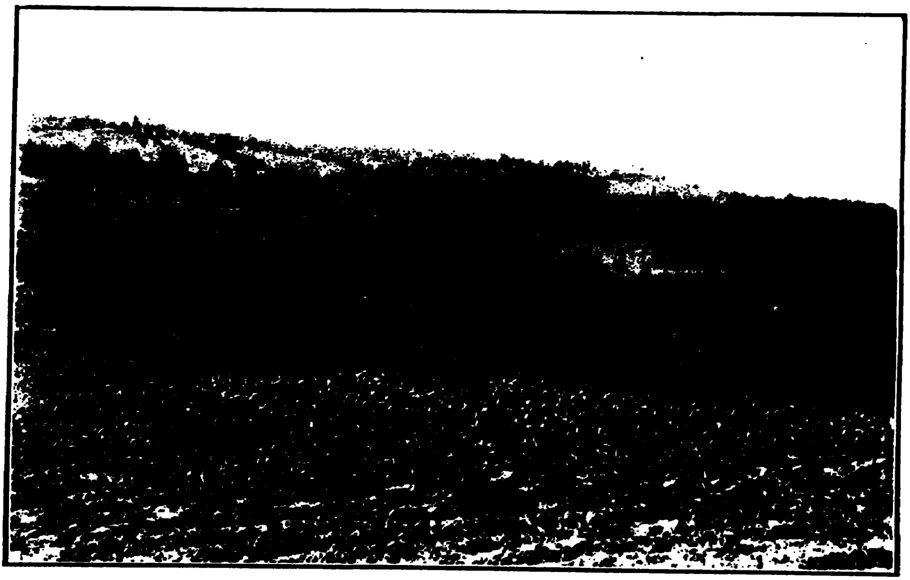

Fig. 2. Topography of Rajgad Shales.
Facing south from one of the knolls near Undwa.

Photos : B. Rama Rao.

PLATE 9

Fig. 1. Interbedding of hornstones and quartzites in Rajgad Shales.
On the hill N.-W. of Adepur.

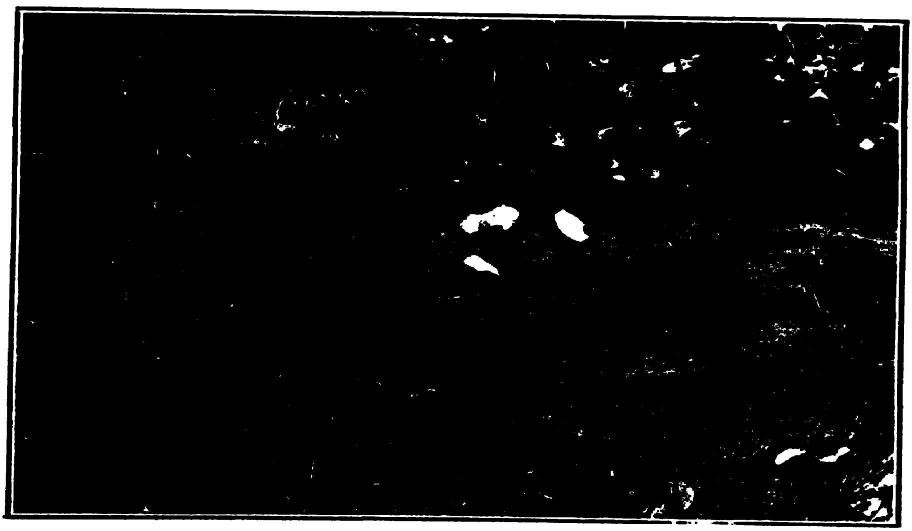

Fig. 2. Mural jointings in porphyritic granite.
On the west bank of the Ujol river, north of Kakalpur.

Photos : B. Kama Rao.

PLATE 10

Fig. 1. Formation of cavities in porphyritic granite due to the scouring out of inclusions. In the hills near Kakalpur.

Fig. 2. Fantastic shape of granite block, produced by scouring out of inclusions and weathering. Midway between Kakalpur and Damavav.

Photos : B. Rama Rao.

PLATE 11

Fig. 1. Formation of galleries and caves in the Haveli porphyritic granite. Near Kakalpur.

Fig. 2. Contact between porphyritic granite, and coarse normal type of Haveli granites. Near Ampliphalia.

Photos : B. Rama Rao.

PLATE 12

Fig. 1. Honeycomb structure in brownish red sandstone. Jhabu.

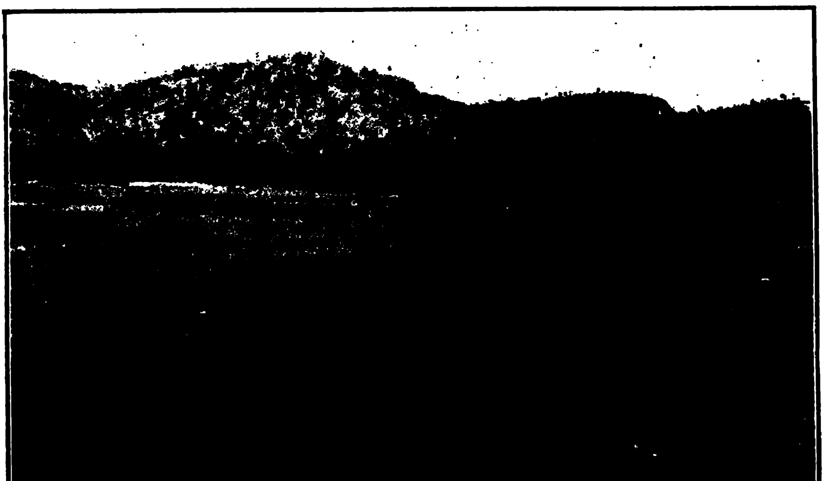

Fig. 2. Amygdular Trap overlying plateau quartzite. (Foreground) Note the scarp face of the trap and scree. Looking west from Anopura.

Photos : B. Rama Rao.

PLATE 13

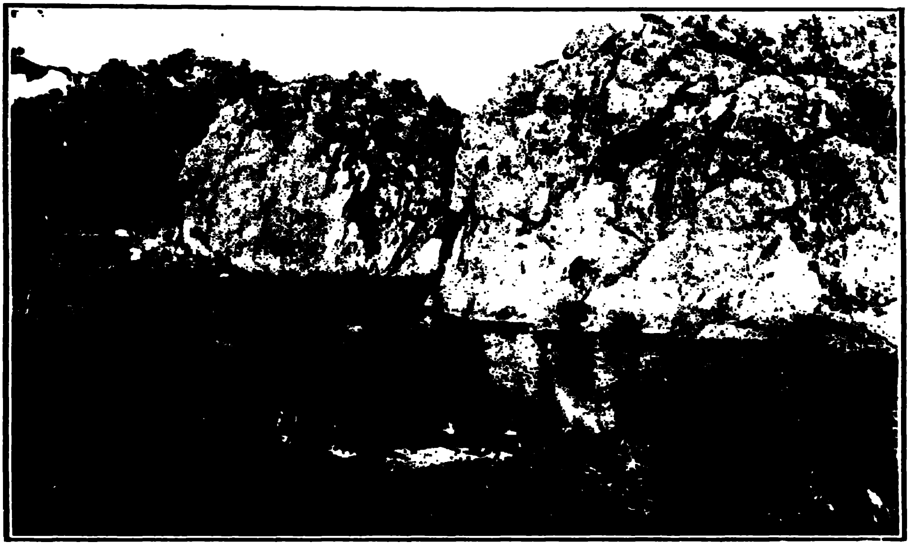

Fig. 1. Winding gorges of the Hadap in massive quartzites. North of Umria.

Fig. 2. A glimpse of our camp on the banks of Ujol. Near Kakalpur.

Photos: B. Rama Rao.

PLATE 14

Fig. 1. Dark hornblende schist. ×22

Fig. 2. Hornblende micaceous gneiss. ×22

Fig. 3. Secondary pyroxene rock. ×22

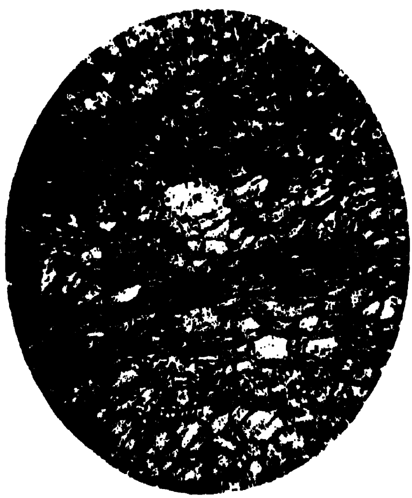

Fig. 4. Grey pyroxene rock. ×22

Photo-micros : K. Sripada Rao.

PLATE 15

Fig. 1. Crystalline limestone. ×22

Fig. 2. Serpentine marble. ×22

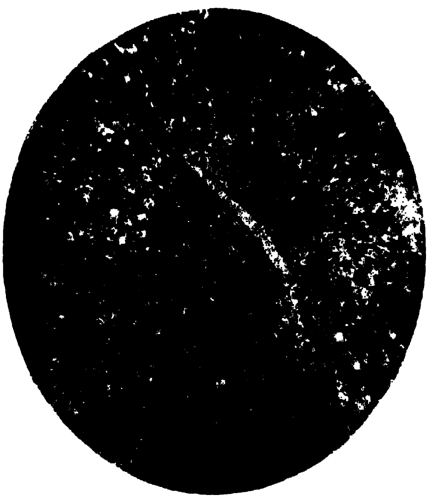

Fig. 3. Poyelli dark grey limestone. ×22

Fig. 4. Felspathic quartzite. ×22

Photo-micros : K. Sripada Rao

PLATE 16

Fig. 1. Felspathic quartzite. ×22

Fig. 2. Felspathic grit. ×22

Fig. 3. Micaceous quartz porphyry. ×22

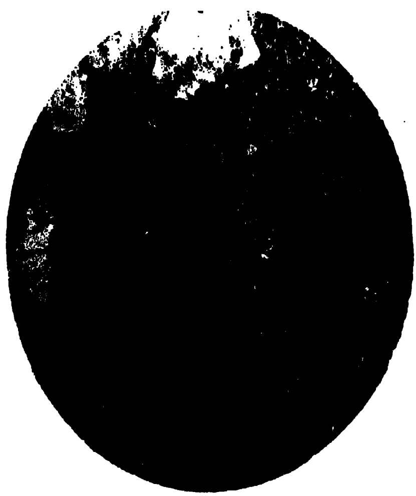

Fig. 4. Matrix rock of Poyelli conglomerate. ×25
(Sericitised quartz-porphyry)

Photo-micros : K. Sripada Rao

PLATE 17

Fig. 1. Hornstone. ×25

Fig. 2. Mica schist with sillimanite. ×22

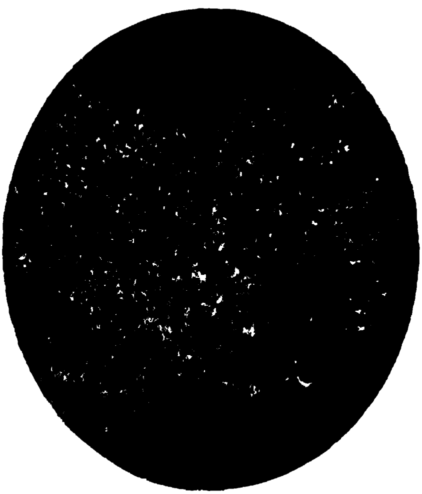

Fig. 3. Secondary amphibole rock. ×22

Fig. 4. Secondary amphibole rock. ×22

Photo-micros : K. Sripada Rao

PLATE 18

Fig. 1. Fine grained Baria quartzite. ×22

Fig. 2. Dark grey Baria quartzite. ×22

Fig. 3. Baria quartzite, pink. ×22

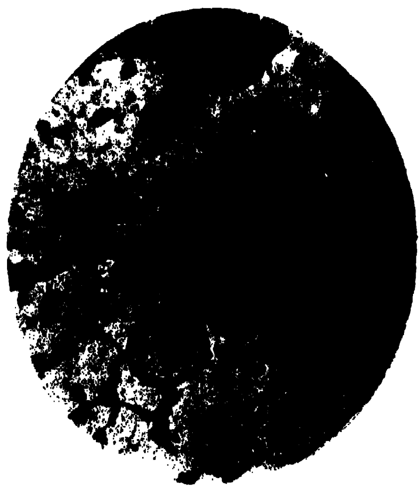

Fig. 4. Friable quartzite. ×22

Photo-micros : K. Sripada Rao

PLATE 19

Fig. 1. Deep pink quartzite. ×22

Fig. 2. "Lameta" grit of Jhabu. ×22

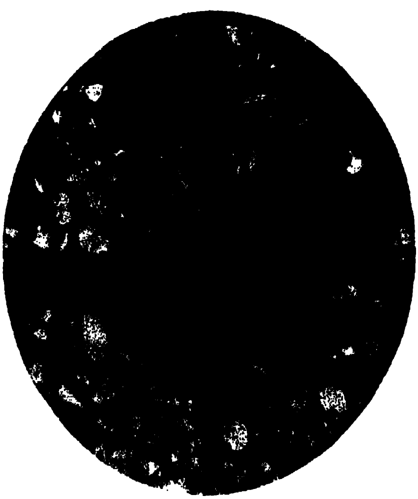

Fig. 3. Calcareous grit of Jhabu. ×22

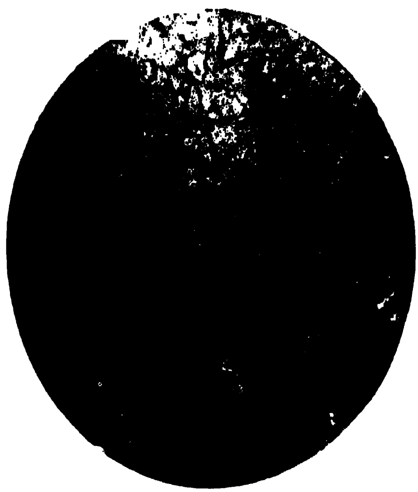

Fig. 4. Siliceous limestone of Jhabu ×22
showing Secondary Calcification.

Photo-micros : K. Sripada Rao

PLATE 20

Fig. 1. Concretionary siliceous limestone of Jhabu. ×22

Fig. 2. Secondary Calcification in Deccan Trap. ×22

Fig. 3. Compact Phase of Deccan Trap. ×22

Fig. 4. Porphyritic type of Deccan Trap. ×22

Photo-micros: K. Sripada Rao